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Vol. 7, No. 1 JULY, 1918

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THE SCIENTIFIC MONTHLY

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THE SCIENTIFIC MONTHLY

JULY, 1918

THE ENGINEERING PROFESSION FIFTY YEARS HENCE II

By Dr. J. A. L. WADDELL, D.Sc., D.E., LL.D.

NEW YORK CITY

IT takes a bold man to endeavor to foretell what changes will occur in engineering during the next fifty years; nevertheless the speaker will make the attempt for the purpose of pointing out a few of the salient possibilities, some of which are easily within reach and should be attained as quickly as possible, while others may, by some engineers, be deemed chimerical. It must be remembered, though, that that highly imaginative French author, Jules Verne, in some of his wildest flights of fancy, was merely foretelling actual occurrences which are to-day so common as to cause no comment.

The speaker has concluded that the most effective way for him to make these various prognostications is by means of an imaginary annual address of the retiring president of the American Academy of Engineers in the year 1968; and he hopes that he will be pardoned for having, when so doing, assumed that the said retiring president is his own grandson and namesake. Such an assumption can certainly do the youngster no harm; but, on the contrary, it may serve him as an incentive to endeavor, should he choose some line of engineering as his life's work.

RETROSPECT

ANNUAL ADDRESS OF

J. A. L. WADDELL, 2d,

Retiring President of the American Academy of Engineers,

Washington, D. C., March 10, 1968

334609

Gentlemen: As retiring president of the American Academy of Engineers in this sixty-eighth year of the twentieth century, at a meeting held specially to celebrate the fiftieth anniversary of the incorporation of the Academy, I have deemed it to be eminently appropriate and fitting to choose as the subject of my address

THE PROGRESS OF THE ENGINEERING PROFESSION DURING THE PAST HALF-CENTURY

In dealing with this subject it has been my aim not only to record the advancement of the engineering profession as a whole, and in detail that of its numerous divisions and subdivisions, but also to indicate the influence which our Academy has had on that development.

As one looks back upon the history of this and other countries since the close of the Great War some forty-eight years ago, he can not help being struck by the immense influence which at every turn engineering has had upon the world's reconstruction and its subsequent development. Almost every step of importance that has been taken was initiated and carried out by engineers; and American technicists in every line have been the ruling spirits in all matters bearing upon the welfare of the nations, taking the lead over the engineers of all the other nationalities, in so far as progress is concerned. The reason for this is that the Great War not only killed off the flower of the European engineers, but also caused most of the European technical schools practically to close their doors, while the United States took the wise precaution of keeping the attendance at such institutions as nearly as possible up to the normal. Of course, the said attendance, immediately after the entrance of our country into the titanic struggle in 1917, was materially decreased by the volunteering into the service of a large proportion of the upper classmen and a smaller proportion of the lower classmen from all of our institutions of learning and especially from the engineering departments of the universities and from the technical and the trade schools; but by the earnest effort of the members of our closely affiliated organization, The Society for the Promotion of Engineering Education, backed by strong pressure from the Administration at Washington, the attendance in the freshman classes of these institutions was at once actually increased a little above normal, and the next year was materially augmented. The result of this wise movement was that as soon as peace was declared and the necessity for world-reconstruction became evident, American

engineers were able to secure not only far more than their *pro rata* share of the work involved, but practically all the important jobs for several years. The hold that they then secured on the engineering work of the world has never since been broken; although, as the European countries commenced to recuperate, their engineers began to get their organizations into better shape, thus reducing somewhat the preponderating influence of the American technicists.

Another reason for that preponderance is that after stupidly doing practically nothing to secure the trade of Latin-America for several years after the war started in Europe, the American bankers, manufacturers and business men finally awoke to the fact that their golden opportunity had arrived, consequently they bestirred themselves and became firmly established in Central and South America, and to a lesser degree in China, before the European manufacturers could get fairly well started again. The smaller success in China was due to the foresight and energy of the Japanese, who established themselves securely in that country while the fighting was still going on. The systematic and combined efforts of American bankers, manufacturers, business men and engineers, applied at the psychological time when nearly all the other peoples of the world were exhausted physically, mentally and financially, resulted ultimately in making the United States the great creditor nation, the American dollar the universal unit of value, and New York City the world's money-center.

In making this retrospect I have been forcibly struck by the greatly increased personal effectiveness of the individual engineer of to-day as compared with that of the individual engineer of the previous half-century. By effectiveness I refer to the extent of the valuable work that a man accomplishes in his entire lifetime. To-day the effectiveness of a high-grade engineer is fully three times as large as it was fifty years ago. For this there have been several causes, among which may be mentioned longevity, education, economics, research, development of a spirit of loyalty, governmental restriction of wasted effort, cessation of war, systematization of technical literature, and increase in number and sizes of technical libraries. I shall take up in the above order and discuss each of these causes.

LONGEVITY

Thanks to the efforts and hard study of biologists, surgeons and physicians, the ordinary limiting life of man has increased from the biblical three score years and ten to a full century.

The studies of the biologists, combined with the coercive work of the Bureau of Sanitation at Washington, have resulted in cutting down nearly to zero the death-roll from all insect-borne diseases, such as typhus fever, malaria, yellow fever, bubonic plague, hookworm, meningitis and mountain fever, as well as other scourges such as smallpox, pellagra, typhoid fever, cholera and leprosy.

The iron hand of the law, combined with a forced enlightenment of the public of all ages and both sexes through the newspapers and the schools, has succeeded in reducing the evil effects of venereal or vice diseases to a very small fraction of their former virulence.

The investigations of the dietetists have taught humanity how best to eat, drink and exercise, not only so as to prolong life but also so as to enjoy it by the possession of good health; and the schools of all grades have taught these doctrines so thoroughly that the unscientific eating and drinking of three or four decades ago is now exceedingly rare. The almost universal adoption of the practise by physicians of giving preventive medicine, instead of trying to overcome disease after it has secured a hold on the patient, has resulted in materially increasing longevity and improving the status of the general health of the community.

The total prohibition of liquor by the federal government in the third decade of the century added, on the average, six years to the life of those men who, otherwise, would have been steady drinkers, besides cutting down crime, profligacy and insanity.

The neutralization of both sexes for crime, insanity, feeblemindedness and bad cases of venereal disease not only has reduced by seventy-five per cent., in a single generation, the number of criminals, lunatics and idiots, but also has had a noticeable effect on the increase in longevity.

While the efforts of certain scientists to prohibit the use of tobacco have proved to be a failure, as far as the populace is concerned, they have succeeded in convincing thinking men that the effect of nicotine on the system is to reduce materially one's mental acumen; consequently a very large percentage of the scientists and engineers of to-day do not use the weed. As a direct result of this there is a small but quite appreciable augmenting of their individual output.

The stamping out of diseases and the increase in longevity have had a double effect upon the improvement of the engineering profession; for not only has each engineer now a greater

number of years than formerly to devote to his work; but also his general health is so much better that he can accomplish much more per hour and can work more hours per day than he did in previous years. It has been noticed, too, that there is a more widespread love for work and mental effort among engineers of all lines and classes than there used to be; and this is very properly attributable to their better general condition of health. Again, if one were to plot the annual effective accomplishment of the average engineer of the present period, it would be seen that the amount continues to increase almost to the time of death, instead of reaching a maximum long before then, as used to be the case half a century ago. By the term "annual effective accomplishment" I do not mean either the number of hours per year that an individual can work or the yearly amount of useful labor that one man can do, but the results that are attained annually through his direction and advice based upon his accumulated experience, and, especially, upon his knowledge of engineering economics.

EDUCATION

During the last fifty years there have been many fundamental improvements in both general and technical education, and these have had much to do with the increased effectiveness of engineers. In the common schools it has been found practicable, without overworking the children, to improve their mentality and increase their knowledge many fold, simply by adopting scientific methods of imparting instruction and by employing a much higher grade of teachers than was customary forty or fifty years ago. In the old days there seemed to be a notion prevalent that if a man or woman were a failure at most things, he or she would do well enough for a teacher, and that there was no need for paying high salaries to instructors. To-day an entirely different view is held, for now teachers as a class are about the best paid people in the community; and their standing therein is second to none.

The most important and fundamental accomplishment in education has been teaching pupils how to think and how, when studying, to concentrate their minds, rather than cramming their memories with a mass of facts, many of which are of doubtful value on account of being subject to change.

The study of vocational fitness of both children and adults which was inaugurated in the early twenties, and which required a full decade to establish as an economic necessity, has done much to improve engineering by preventing the unfit from entering its ranks.

In respect to technical education, thanks to the Society for the Promotion of Engineering Education, it may be stated that the methods governing it have been fundamentally changed. In the old days many insufficiently trained young men, and many who were intellectually and temperamentally unfit, were allowed to enter the technical schools, where during a period of four years they were stuffed with facts *ad nauseam*, with the result that the graduates were not deep thinkers; besides which, they were sadly deficient in those lines of education which were not purely technical. They were, in short, highly trained human machines, capable of earning a living in the employ of some large manufacturing or contracting company, but incompetent either to take their places as worthy citizens, or to originate things of real value by concentrated mental effort.

After many experiments and failures, it was learned that engineering cannot be taught in a four-year course, and that an engineer's education should cover many studies besides those of pure technics. Again, it was learned that it is bad policy to try to train all engineering students for the same ultimate object, because some men will do well as subordinates and others as leaders and originators. The ultimate solution of the problem of technical education was the establishment of three kinds of technical schools, viz., trade-schools for the rank and file, or for those who by their individual limitations are doomed to mediocrity; broad engineering courses for good students, teaching them thoroughly mathematics, the humanities, economics, elementary technics and general culture; and postgraduate schools for the best of the technical graduates, giving elaborate instruction in both the theory and the practise of the various special lines of work. The result is that the profession is now well supplied with capable "hewers of wood and drawers of water"; that there is turned out annually a large number of highly cultured and broad-gauge young men who are drilled in the elements of technics, who are well fitted to begin service in almost any line of activity, and who will be able to advance rapidly therein; and that there is an adequate number of specially trained technicists who can at once successfully fill important positions.

Economics

Up to the beginning of the third decade of the century, but little attention had been paid by engineers in general or by instructors in engineering to the important subject of "Economics." It is true that the leading American engineers had individually studied deeply into the matter when making their

designs, and that a few of the technical writers (especially in bridge subjects) had touched upon the question; but it was not until 1915, when the Society for the Promotion of Engineering Education appointed a special committee on "The Study of Economics in Technical Schools," that a systematic effort was made to devote due attention in such schools to that fundamentally important feature of engineering. The result of the committee's report, which was presented in 1917, was ultimately the publication under the auspices of that Society of an elaborate treatise on "The Economics of Engineering," written by a large number of specialists in all lines of technical activity. This book served as a basis for the preparation of other works more suited to students' use; and the study of economics in all the technical schools of the country was soon thereafter undertaken in earnest, with the result that to-day all engineering projects are much more economically handled in respect to both design and construction than they used to be. I might mention that in the accomplishment of this great desideratum our Academy cooperated most effectively with the Society for the Promotion of Engineering Education.

Incidentally, it might be stated that the economics of engineers' time and effort have been made the subject of much deep thought, and that important results have been accomplished thereby through time-and-labor-saving devices such as the slide-rule, the pantagraph, the integrating machine and numerous other mechanical computers, through systematization of the individual's work and the avoidance of duplication in investigations, and through the thorough checking of all calculations and plans before work thereunder proceeds.

The compulsory introduction of the metric system of weights and measures about the end of the third decade of the century, while at first proving to be a hardship and an expense to most people, and especially to engineers, eventually became a great time-saver for all computers.

As a side-issue in the matter of economics, I might mention that, over forty years ago, the federal government, as a matter of political economy, undertook the storage of grain and other food products so as to carry over the surplus from the years of plenty to the years of scarcity, and thus to equalize both the earnings of the producer and the general cost of living. Large grain bins and cold-storage plants were built and operated by the government in all parts of the country; and the result of the movement has been eminently satisfactory. Parenthetically, I might state that this step inaugurated a campaign of ex-

termination against rats and mice, which was later extended to include all useless cats and dogs. The economy effected by this campaign amounted to some hundreds of millions of dollars annually; consequently it has been made a permanent institution under federal-government control.

Research

Up to the third decade of the century the work of engineering research was handled mainly in the universities and technical schools, although the Bureau of Standards at Washington had been making many important investigations; but since then the greater part of such research has been done by the federal government through that bureau, and on a much larger scale than formerly. The beneficial effect on the profession of the results of the many researches in all lines of technics is simply incalculable. By its recommendations to the federal government concerning proposed investigations and by suggestions of its own thereto, our academy has rendered most effective service in this line of activity.

Development of a Spirit of Loyalty

Regarding loyalty to the profession, Sir Francis Bacon said:

> I hold every man a debtor to his profession, from which as men of course do seek to receive countenance and profit, so ought they of duty to endeavor themselves, by way of amends, to be a help and ornament thereto.

The development of a spirit of loyalty to our profession has been a slow process, spread over a long period of years; but I am happy to say that to-day it pervades all ranks of engineering and is the mainspring of both individual and concerted action in all matters professional. The instruction of engineers in respect to the necessity for professional loyalty was the work of the various technical societies of the country, which were systematically instigated thereto by the American Academy of Engineers. The members of our organization take great satisfaction in this accomplishment.

Governmental Restriction of Wasted Effort

While it is true that, in the early days of modern engineering, the factor of competition in design and the stimulation to mental effort which it produced had much to do with the advancement of American engineers ahead of their European brethren, it was gradually carried to greater and greater excess until it resulted in being a heavy burden upon the profes-

sion. It became customary among municipalities and the promoters of enterprises to advertise for competitive studies and plans. Sometimes, but by no means always, they would offer a small prize, hardly large enough to cover the cost of a single set of papers, the real bait being the promise of the engineering to the successful competitor. In many cases the project failed to materialize, in others even the payment of the prize was dodged, and it was not an uncommon occurrence to have the total expenditure on studies by the numerous competitors far exceed the net amount of the total fee earned by the successful competitor.

Some forty years ago, the academy took hold of the matter, pointing out the injustice done to the profession, and succeeded in having Congress pass a law making all such competitions illegal, and providing that any person, company, or community desiring competition on engineering or architectural projects or plans must limit the number of competitors, must pay each unsuccessful competitor a fee large enough amply to cover his entire expense in the competition, and that the prize for the successful competitor must be either retention on the work at the standard rate of compensation, or a sum of money at least five times the amount of the expense to which he is put in preparing his competitive papers, the actual amounts of the payments being settled in advance by agreement between the promoter and the various competitors. This law, while cutting out all illegitimate and unnecessary competitions, has not militated materially against the public's receiving, whenever necessary or advisable, the benefit of competitive effort; but it has proved a great boon to the consulting and independent engineers of America. The Canadian Academy of Engineers, which was established in 1923, soon followed our lead in this movement, and succeeded in having similar legislation passed by the Dominion Parliament.

Cessation of War

The sudden cessation of war throughout the world, after the conquering of the Central Powers by the Allies nearly a half-century ago, with the establishment of permanent peace by means of an armed alliance, and with the subsequent gradual reduction of the policing armament which ensued as the nations became accustomed to arbitration and alive to its wonderful advantages, permitted some of the best brains of the world to turn from thoughts of destruction to those of construction; and thus the engineering profession received the benefit of an increased amount of highly skilled labor and inventive genius.

To-day any invention of an instrument of destruction is frowned upon by all thoughtful people; and any one who advocates war in any shape is treated as a public enemy and punished accordingly. As a result of the successful establishment of world peace, Congress in 1937 changed the name of the War Department to that of "Peace Department," and the name of the Navy Department to that of "Navigation Department."

Systematization of Technical Literature

By the suggestion of our academy, the federal government in 1923 undertook to issue annually (and later semi-annually) a pamphlet giving for each engineering specialty a list of the best and most useful technical books published in the English language, and indicating in condensed form their contents. This is kept up to date by the direction of a committee of the academy, all books being dropped from the list as soon as their practical usefulness ceases. The result of this innovation has been to enable both individual engineers and the libraries of schools and municipalities to purchase the treatises they need without squandering their money on works that will be of no practical assistance.

Increase in Size and Number of Technical Libraries

The mass of technical literature has gradually become so large that it is impracticable for most engineers to purchase all the books they need; consequently, at the request of our academy, the federal government has initiated the custom of making allowances to public libraries for the purchase of technical works. It is, therefore, practicable for an engineer located in a city of any size to find all the references he needs in his work without having a large library of his own. This arrangement has been of great service to the profession, especially to its younger members.

Some of the other important items of influence in the general improvement of the status of engineering during the last fifty years are the following: The establishment of the American Institute, the inauguration of the Department of Public Works, the Federal licensing of engineers, the permanent alliance of labor and capital, the formation of the Industrial Army, the reform of the Patent Office, the universal distribution of power by the government, the enforced conservation of materials, the utilization of by-products, the proper restriction of the employment of the term "Engineer," the avoidance of

disasters to great engineering constructions through extra checking of plans, the establishment of a code of engineering ethics, the inauguration of legalized distinctions, the determination of minimum charges for services, the improvement of technical literature, the systematic promotion of projects, the working of American engineers abroad, the installation of concerted publicity movements, and, finally, the due recognition of the profession by the nation. As before, I shall discuss each of these items in the order in which they are mentioned.

American Institute

When the founders of our academy first proposed its formation, they had a still greater step in mind, as was indicated in public on several occasions, viz., the establishment of an American Institute on the lines of *L'Institut de France*, to include besides our own organization the then-existing National Academy of Sciences and all future duly-organized American academies, such as those of Architecture, Medicine, Literature, Law, Journalism, Art, Political Economy and Universal Peace.

During the third decade there were established only three of these academies, making five all told. Then the dream of the founders of our academy came true, for the American Institute was formed in 1927; and within the next five or six years the other academies just mentioned were organized, each one, as soon as established, becoming a member of the institute. This organization holds regular meetings only twice a year; but occasionally it has called a special meeting to discuss and take action upon some burning question of the hour. The fine building for the institute, in which are located the headquarters or offices of all the component academies, was presented by the federal government in 1929 at a cost of about twenty million dollars. The bringing together of engineers and other learned men from the various walks of life to discuss matters of great moment in which their lines cross has done much for humanity; and especially has it benefited the engineers by forcing them out of the narrow ruts into which they constantly tended to fall, and broadening them by contact with many of the most brilliant minds of their compatriots.

A number of special meetings in the Institute House of two and sometimes three academies have been held for the purpose of taking action on questions in which they were jointly interested; and these meetings also have been found eminently productive of good for the commonwealth. Among other benefits obtained in this manner might be mentioned the partial purifica-

tion of politics (it would prove an impossible task to cleanse it thoroughly!), the remodeling of the American diplomatic service so as to make it superior to that of any other nation, and the reform of the Patent Office.

Department of Public Works

The first great task undertaken by our academy was the establishment of a Department of Public Works to take over all the engineering work which had hitherto been distributed rather illogically among several of the departments of the government. It required a hard fight to accomplish this; but the results have proved, beyond the peradventure of a doubt, the importance of the measure. This department is practically removed from politics, because its secretary (always a civil engineer of high standing, undoubted attainments and special fitness) continues to hold his position in spite of changes of administration, retaining it as long as he is mentally and physically fit to attend properly to the work of his high office.

Licensing of Engineers

During the second decade of the century there had been much controversy among engineers concerning the advisability of not permitting technical men to practise without first securing a license. Many were the arguments advanced by both sides, and most of them were sound. Those favoring the movement declared that engineering could never attain to its full measure of public respect without the license system, while those opposed stated that the control of their professional activities by the numerous states would be intolerable. A compromise was finally effected by a general agreement to accept a federal license, based upon broad lines, and to repeal the few state technical-license-laws that had already been put into operation. As you all know, the result was eminently satisfactory. Not one of us would be willing to revert to the non-license days.

I do not believe that any one would dare to contradict me when I claim that the credit for the satisfactory settlement of this long-mooted point belongs to the American Academy of Engineers.

Alliance of Labor and Capital

Up to the year 1929, from time to time there had been struggles of a bitter nature between organized labor and capital, to the great detriment of progress in all lines of business. These

disagreements seriously interfered with the work of engineers by paralyzing the progress of their constructions and by discouraging the investment of money in sound enterprises involving engineering. The conditions finally became so bad that nobody could safely undertake to materialize any large project. It was then that our academy stepped into the breach, and, after several years of continuous effort, succeeded in forming an amalgamation of working men, contractors, manufacturers and bankers which has been the means of absolutely preventing strikes, every incipient dispute now being settled by arbitration. Organized strikes of any kind are to-day treated as "conspiracy" by the laws of the land.

Industrial Army

Some forty years ago when our standing army was finally reduced to a mere police force, the government recognized that some similar body was necessary in order to provide labor for the unemployed; hence it inaugurated the "Industrial Army," composed mainly of volunteers, but also having some regiments recruited solely from the hobo and the minor-criminal classes. These men are drilled and trained in the lines of peace as formerly were soldiers in the lines of war, so as to make them effective. They are sent out on public works, and their services are occasionally loaned to the large contractors. They are paid monthly and are fed and clothed at government expense. Their services have proved of great value in agriculture; for, owing to their mobility, they are sent from south to north in the harvest season, then shipped south again and gradually moved northward so as to care for the plowing of the land and the cultivating of the crops.

There are separate regiments for the different kinds of work; but in case of necessity, the character of the men's occupation is changed. The enlistment period is four years; and deserters are punished just as drastically as were formerly those from the military army and the navy.

The establishment of this industrial army has proved to be a great boon to the engineering profession, in that there is at all times a certain amount of dependable labor which can be utilized on important constructions. Moreover, it tends to stabilize the price of labor, and thus encourages promoters and contractors to undertake great enterprises.

Patent Office Reform

The reform of the Patent Office was a hard nut to crack, but by working jointly with the American Academy of Law we managed to accomplish it. In former times that office was a standing joke. Anybody could patent almost anything; and conflicting patents were quite common. The government evidently was of the opinion that any one who was not satisfied with the way his patent was recognized by his competitors could secure satisfaction by an appeal to the law; but that process usually proved to be interminable and exceedingly expensive. Engineers considered that a patent was simply a club with which to frighten off intruders—and as such it often proved a failure. Again, it was customary to grant patents for the most minor details of design and for the smallest kinds of improvements, notwithstanding the fact that some eminent jurists declared such patents to be invalid.

To-day all such conditions are changed. Patents are being granted only for those things which are truly innovations; and it is almost unheard of to find one patent conflicting with another. To accomplish this is what the Patent Office officials are paid to do; and no shirking of the responsibility is any longer permitted.

Power Distribution

One of the most fundamental and drastic actions ever instituted by the federal government was the permanent taking over by it of the entire power supply of the United States and making the unit prices thereof the same in all localities, the exact schedule rate to the consumer being dependent to a certain extent on the amount he uses regularly. The results of this innovation were a marvellous economy of energy for the nation, a universal satisfaction on the part of all power users, and an almost automatic adjustment of fairly uniform production throughout the entire year.

All kinds of power are included. All large waterfalls are utilized, even to the total drying up of Niagara Falls, except for two hours on each Sunday afternoon during the months of May to October, inclusive, at which times, as you know, only enough water is allowed to pass over the falls to produce the desired scenic effect.

Coal is now burned mainly at the mouth of the mine instead of being transported long distances at great expense by rail—in fact for a while the experiment was tried of burning it *in* the mine; but this was soon abandoned after several costly conflagrations had occurred.

Natural gas is employed somewhat for power purposes; but generally it is found more satisfactory to pipe it to the cities for domestic use.

Following the lead of an eminent Italian engineer, we have been endeavoring with more or less success to utilize the internal heat of the earth; but there are only a few places in our country which are suitable for this process of power production.

For a long time it was thought that the utilization of tidal energy could not be made a paying enterprise, but in the early thirties a successful plant was built in New Brunswick to harness some of the power of the noted tidal bore. Both ebb and flow were utilized, although not to the same extent. Of course, only a small portion of the energy of the flowing water could be impounded, but there is enough and to spare at that locality. Afterwards, the employment of tidal energy was done on a commercial scale and upon a paying basis at a number of places in the United States; but it is not a very economic way of obtaining power.

The extraction of energy from wave motion, as suggested by Joseph Tomlinson, a noted Canadian engineer, as long ago as 1876, has never proved to be a commercial success, because the cost of the apparatus is too great in comparison with the value of the energy collected. It does pay, however, in the case of small, isolated lighthouses where to convey the required energy from the mainland would be either impracticable or very expensive.

The great improvement that has lately been effected in the efficiency of sun-power motors has enabled us to utilize direct solar energy upon a commercial basis in the states of California, Arizona, New Mexico and Western Texas, also in the Territory of Lower California. The last was purchased from Mexico in 1920 after the cessation of that country's series of continuous revolutions, in order to give it money to pay all legitimate claims for damages to the Mexican properties of American citizens and British subjects, and to enable it to carry on its government during the period of reconstruction.

The products of all the power-producing plants are combined and distributed in the most economic manner practicable, the method varying with the time of year and with the hygrometric conditions of the various districts. The ability of the government to distribute the power throughout the country, economically and as desired, is due mainly to a most important discovery by an American metallurgist of the alloy "electroconite," which, in the form of wire, combines a satisfactory

strength with a resistance of only about one tenth of that of the best previously known conductor.

The credit for establishing the government control of the manufacture and distribution of power is due essentially to the constant and systematic efforts of the American Academy of Engineers.

At one time the wireless transmission of power was seriously considered, and, in truth, it was shown to be a possibility; but when trying it on a commercial basis there developed so many unanticipated obstacles that it was abandoned. Similarly, it was shown to be feasible to produce electric energy directly from coal, but practically it was found more economical to burn it. Greatly improved methods of doing so were discovered, so that to-day there is utilized a far higher percentage of the energy of the coal than was even dreamed of formerly.

Conservation

The conservation of the country's resources for a long time occupied the attention of many prominent, far-sighted and patriotic Americans, who pointed out that eventually the nation would assuredly come to grief, unless it ceased wasting its resources. While their preaching was not altogether without effect, it was not until 1938 (when the joint efforts of the American Academy of Economics and our own organization induced the government to establish a Department of Conservation) that effective measures to curtail waste were established and enforced. The result has been a decided benefit to our profession, in that now we all know what materials can and what can not be used for our constructions, and that the public will not be allowed to bring the commonwealth to poverty and disaster by needless waste.

Utilization of By-products

In the beginning of the twentieth century, the study in America of how best to utilize by-products was begun; and it was carried on in a rather desultory manner in the universities and some of the technical schools. The University of Kansas made a rather spectacular start in this line of research, the work being carried out upon a strictly business basis, and achieved quite a success; but soon thereafter, owing to a change in the personnel of the faculty, the endeavor was dropped.

It required the advent of the Great War in Europe to teach Americans that they must make themselves independent of the rest of the world by manufacturing at home all the necessaries

of life for both peace and war. This condition aroused to action our chemists and chemical engineers, and incidentally caused them to study the utilization of by-products, thus materially increasing the wealth of the nation.

Restriction of the Term "Engineer"

It seems almost ridiculous or impossible of belief that the long-continued misuse of a name should seriously militate against the proper appreciation by the public of a great profession; but such certainly was the case. The term "engineer" formerly was applied indiscriminately to locomotive drivers, electric motor men, stationary-engine men, and even to the operators of insignificant gasoline engines, as well as to the members of the engineering profession; and the public was unable to distinguish clearly between the highly trained professional man and the roustabout engine-manipulator. For long years our profession failed to receive due public recognition; and this absurd misconception of terms was one of the principal reasons therefor. The trouble was finally overcome by the concerted action of the leading technical societies, both national and local, the members of which pledged themselves on every occasion to correct, either orally or in writing, every misuse of the term, irrespective of the standing or character of the delinquent. It did not take more than a twelvemonth to establish the change upon a permanent basis.

Avoidance of Disasters by the Extra Checking of Plans

About the end of 1917, after having had the idea in mind for several years, a well-known engineer-author suggested in the technical press that, in order to avoid disasters to great public or private engineering constructions, such as the two which occurred to the famous Quebec Bridge, all the plans for such structures should be thoroughly checked by an engineer or engineers of the highest standing who had not been in any way concerned in the making of the design, the compensation for such checking being paid by the client and not by the designing engineers. Although the scheme met with some opposition at first, it was eventually adopted. The non-occurrence of any great disaster of the kind during the last four or five decades affords ample proof of the wisdom of the precautionary expedient.

Code of Engineering Ethics

For many years our profession struggled along without having an established code of ethics—much to its detriment. Various technical societies made half-hearted attempts to establish codes, but most of them were "to laugh." A code suitable to one society did not prove acceptable to some of the others, and the large societies could not agree on the matter; but soon after the organization of our academy, we took hold of the subject methodically and energetically, and by means of a small committee, representing the principal lines of engineering activity, succeeded in evolving a code, which, after some slight modifications that were made to suit the desires of certain of the larger organizations, was accepted universally as standard. With the exception of a few minor changes made of late years, it is the code under which we all are now operating, and by which we are strictly governed in our dealings with each other, with our clients, and with the public.

Distinctions

Up to the time that the United States entered the Great War, there was a popular prejudice in our country against decorations and titles, on the plea that they were undemocratic; the government itself going so far as to prohibit its paid employees from accepting any foreign order of knighthood or any similar distinction, except through a special act of Congress. No matter, though, how much quiet sneering was done by Americans about the acceptance of foreign decorations by private citizens, it was to be noticed that none of them were ever rejected when offered.

Owing to the fact that in 1917 some of the governments of the Allies offered distinguished-service decorations for gallant conduct to several American soldiers, and that permanently to refuse them permission to accept the honor would have been discourteous to our friends, Congress early in 1918 repealed the law which prohibited the paid employees of the government from accepting orders, medals and other decorations from foreign governments. The result was that by the end of the war the "decoration habit" had taken such a hold on the American people that ere long several orders of knighthood and merit were formally established by Congress. Fortunately, the distribution of these honors has been kept absolutely free from political control; and to-day American men of learning prize these decorations far more highly than they do any pecuniary

rewards that they receive in compensation for their professional services.

Minimum Charges for Professional Work

After years of effort on the part of the American Institute of Consulting Engineers, that society finally succeeded in having Congress pass a bill placing an inferior limit on the compensation for engineering services; and the profession ever since has been trying, with more or less success, to force its members to live up to the requirements. Our academy, while not actively engaged in this endeavor, gave the institute its moral support. The observance of this law has not only directly increased the compensation of the independent engineers but also indirectly has been the means of augmenting that of their salaried brethren; besides, it has raised the profession greatly in the estimation of the public.

Improvement of Technical Literature

Although the technical literature in America during the first two decades of this century was far superior to that of the preceding century, there was still considerable room for improvement. There were too many books on the market which either were merely compilations or were without *raison d'être*. Most of these were written by either professors of engineering who did not possess the necessary practical knowledge or by young practitioners, ambitious to make a name for themselves before they had earned their spurs.

By the appointment of a standing joint-committee of the Society for the Promotion of Engineering Education and our academy, and through an unrecorded understanding with the leading publishers of scientific books, no technical treatise will be published by these companies unless it receives the written approval of that committee. Moreover, in order to save authors' time, the committee stands ready to advise with would-be authors concerning any proposed treatise before actual work is begun on the preparation of the manuscript, or at any time subsequent thereto. The influence of this committee on the character of American technical literature has been marked. The quality has been improved, while the quantity has been lessened.

(To be Concluded)

WEATHER CONTROLS OVER THE FIGHTING DURING THE SPRING OF 1918

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THE military operations of the present spring (1918) have been of such critical importance in relation to the probable outcome of the whole war that all factors which have played any part in the fighting deserve careful attention. In the following article, the part played by meteorological controls is set forth as fully as is possible at this time. The facts here included have been collected from the regular official despatches, and from the reports of reliable war correspondents and military experts. It is obviously not possible, as yet, to do full justice to the subject, and some of the facts here included may need revision when fuller information becomes available.

Throughout the late winter and the first three weeks of spring, the probable date of the expected German offensive was a matter of momentous interest. No really active winter campaigns have been carried on in the western war zone. As a whole, the season of aggressive military operations has been April to November. In 1915, the spring campaign may be said to have begun on April 22. In 1916, the German Verdun drive was begun in late February (21st), at a season meteorologically unfavorable, in order, probably, to forestall the expected British and Russian spring drives. In 1917, the British inaugurated their offensive about Arras on April 9. Spells of warm, thawing weather characteristically come with increasing frequency in March and April, but unless the season is "early," major operations are more than likely to be held up by storms and bad roads until spring is well established. During last February (1918) there were, as usual, fogs, heavy rains and bad roads, but the increasing number of fine, warm days, accompanied by drying ground, caused the Allied commanders to expect an early German offensive. March "came in like a lion," with gales and snowstorms; heavy rains and cold, and then followed alternating spells of fine and warm, and of cold and stormy weather.

The great German offensive began on the early morning of March 21. From all the evidence that has so far come to hand

it is clear that the time must have been carefully chosen after consultation with the meteorological experts. It was a spell of fine, dry weather ("exceptional weather favored his [the enemy's] designs"), and dry weather is one great essential, especially in the low country on the Western front, for the rapid movement of troops, of ammunition and of supplies. With heavy rains, deep mud and impassable roads, no quick, effective advance can be made. A dry spell in western Europe usually means that there is a well-developed area of high pressure to the eastward. This type of weather, when well established, is not unlikely to last for several days, longer, as a rule, than dry spells usually last in the early spring in the eastern United States. In western Europe, such spells bring easterly winds, which are often chilly, and also night fogs. Easterly winds are, furthermore, obviously favorable for the use of gas by the enemy, and also carry the smoke of artillery firing to the west, thus helping to screen the attacking troops.

Such conditions, easily inferred by any meteorologist who has a knowledge of European weather types, prevailed during the first ten days of the German offensive. All the meteorological factors were in favor of the enemy. The attack began in a thick fog along much of the front. The enemy advanced in many places unseen by the Allied troops, the smoke cloud also helping to serve as a screen. Gas was successfully used in various localities. The Allied gunners could hardly see their own horses; the firing had to be more or less haphazard; the infantry was obliged to advance without adequate artillery preparation. The surprise of the British 5th Army was largely attributed to the fog. Airplane observation was difficult along much of the front. In some places the fog evidently threw the assaulting German troops into confusion, the different units being temporarily unable to join forces as had been planned. As was to be expected, the easterly winds soon became colder, and the troops were reported as needing heavy overcoats, especially at night.

This spell of fine dry weather lasted, with but a few local and temporary interruptions in the way of showers or snow flurries, for a little over a week, but it was a week during which the enemy was able to make very considerable progress. Then heavy rains set in, continuing off and on, in spells, as is usual in the spring in Flanders. The Germans were at once greatly handicapped because of the difficulties of moving their troops, artillery and supplies through the deep and sticky mud. The weather conditions were then in favor of the Allies. The Ger-

mans had simply outrun their guns. There was some respite from the incessant German attacks, and there was time to perfect plans and to strengthen defenses. The mud did not hamper the Allies as much as the Germans, because the roads back of the Allied lines had not been so badly broken up by the gun-fire. The German papers mentioned the handicaps resulting from the rains, and explained the slackening of their offensive as being due to the weather. There is no reason to doubt that this was at least in part the case. It is clear that the condition of the roads, especially when the distance from their starting point was taken into account, made it unwise, if not impossible, for the Germans to continue their attempt at that time to break through between the British and French armies. The heavy rains may have played a more important part than many people imagine.

During the renewed German offensive, early in the second week of April, the enemy again took advantage of a thick early morning fog, during a dry spell, when the ground was hard. It was quite impossible for the Allied troops to see the enemy until the latter was very close to the front lines.

The April despatches make frequent mention of alternating spells of rainy and of fine, sunny weather; and of many German surprise attacks made in fogs (as, *e. g.*, at Mt. Kemmel on April 26), which are very frequent at all seasons on the western front. During the first week of April several days of rain brought a general suspension of major operations. Mr. F. H. Simonds, in his weekly account of the war, wrote:

> Perhaps if it had not rained he (the enemy) might have gotten through, just as Victor Hugo and other French writers insist that Napoleon would have won at Waterloo if it had not rained the night before, and delayed the French attack the next morning.

The dry spells were at once taken advantage of by the aviators for reconnaissance work and for bombing, and by the Germans, for renewed attacks. On April 20 there were reports of belated snow-squalls, and of inclement weather, accompanied by a temporary lull in the fighting. An interesting illustration of the marked attention paid by the Germans to meteorological conditions is found in the arrangements for moving troops in different weather conditions. According to press despatches,

> Orders are issued under which in the first zone, on clear days, foot troops may not move in any greater number than four men together, mounted men not more than two together, and vehicles not more than one at a time, with a minimum distance of 300 yards between groups. The

restrictions are relaxed when the weather is not clear, so as to permit the movement of groups of forty infantrymen, twenty cavalrymen, and ten vehicles. In the second zone it is permissible to form groups of the size allowed in the first zone on hazy days, but there must be intervals of 500 yards. In this manner movements generally escape attention.

Heavy rains fell on several days early in May; the roads were in very bad condition; shell-holes and all depressions were filled with water. That the expected renewal of the German drive was thereby delayed is undoubted. It is to be expected that, when so much depends upon the most favorable combination of all possible elements which may make for success, the enemy will wait for favorable weather conditions before attempting a general attack. To advance when the quick movement of reserves, of guns, of ammunition and of supplies is impossible, owing to the condition of the roads, is to run a very unnecessary risk. Several days of very fine weather, reported after the middle of May, were not accompanied by a renewal of the German offensive. One correspondent suggested that what the enemy wanted was misty, foggy conditions, such as he chose at the beginning of the first great advance on March 21. A Paris despatch, May 18, also intimated that "the beginning of the offensive by which the Germans expect to achieve final success now depends solely on weather conditions."

There is no doubt that the enemy took advantage of every spell of fine weather to improve his roads, and to bring up supplies and ammunition. One of the best-informed of the war correspondents, Mr. Philip Gibbs, wrote under date of May 24:

> Heavy rainstorms have broken up the fine spell of sunshine which made this May so splendid. This change does not fill us with regret, because dirty weather now may be in our favor, and hinder the enemy in his offensive schemes. . . . Bad weather, however, acts against both sides, and though they (the Germans) should be held fast in the mud, the British do not want to lose visibility for their flying men or machine gunners. . . . The enemy is very cunning in making use of climatic conditions, and adapts his methods to them.[1]

Berlin despatches, dated May 25, stated that the bad weather was preventing active operations.

The German offensive was renewed on May 27. At the time of sending the present article to the press, very few details regarding the meteorological conditions are available. So far as information has come to hand, it appears that the weather was fine, with bright moonlight at night. One Berlin despatch, of May 29, notes changeable weather. The delay in opening this new offensive has been ascribed, by one correspondent, to the

[1] New York *Times*, May 25, 1918.

desire of the Germans to postpone their attack until better weather conditions in the Trentino sector should make it possible for the Austrians to begin their offensive in that area.

There have been several interesting occurrences in connection with the use of gas. On April 10, four regiments of Prussian Guards were reported as having suffered severely during an attack on Armentières, when the wind shifted suddenly, and blew their gas back in their own faces. On May 12, another similar case was reported, the enemy becoming disorganized in consequence. A Swiss report dated Geneva, May 7, noted that the municipal authorities at Mülhausen, in Alsace, had ordered all inhabitants to obtain gas masks as a protection "against aerial gas attacks." The statement added that, owing to the prevalence of westerly winds, great quantities of the poisonous gases used by the Germans on the western front had drifted east, toward the Rhine. This story is hardly credible, for the gases are rapidly diffused and diluted when carried far by wind. It is worth noting that the Germans are now using gases in four ways. First, gas clouds, which depend on a favorable wind; second, projectors, which also depend on the wind; third, long-range artillery gas shells; and fourth, hand grenades. The direction and velocity of the wind enters as a critical factor in the first two cases. In connection with gas attacks of the first sort a good deal of information is now available. We know that the German "gas regiments" contain a considerable number of trained meteorological observers, who watch the current weather conditions. While the gas goes with the wind, it is clear that topography plays a part in its diffusion, which is best in a flat country, and poorest in a broken country. A recent writer, Major S. J. M. Auld, has told us that the outline of the trench system and the angle at which the wind is blowing are carefully correlated, in order that the gas shall not be driven back into any part of the German trenches. A "factor of safety" is determined for the angle between the wind direction and the line of the trenches. Ordinary gas attacks are not made when the wind direction is within about 45° of any trench within gassing distance. Further, details as to the most favorable wind velocity have been forthcoming. If the wind is too strong, the gas is dispersed, or moves too fast. If the wind is too light, it takes the gas too long to cross "No Man's Land." Very light winds are also more likely to change their direction than stronger winds, and may blow the gas back into the German lines. The best winds blow between 4 and 12 miles an hour. A wind of 8 miles carries the gas cloud about twice as

fast as a man moves away who retreats rapidly. It is perfectly clear that the German meteorologists have made very careful study of wind and weather before launching such gas attacks, and their success, in a large majority of cases, shows how well their weather forecasts were made.

From the eastern front there is naturally very little to report. Here it was the ice—the result of the cold winter of the Baltic and its adjacent gulfs—that played a part. A Petrograd despatch, dated March 15, noted the movement of 3,000 German troops from the Aland Islands to the coast of Finland in transports, preceded by an ice-breaker. A later despatch (April 7) reported that the Germans were marching from the Aland Islands across the ice at the mouth of the Gulf of Bothnia towards Abo, on the coast of southern Finland, and that the arrival of the German fleet off the Finnish coast threatened the safety of the Russian ships at Helsingfors, which were unable to escape owing to the lack of an ice breaker. A British Admiralty statement, issued May 16, noted that several British submarines were frozen solidly in the ice in the harbor of Helsingfors at the time when the German naval forces were approaching. It was suggested that the ice be broken up around the submarines, and that they should then attempt to dive under the ice and reach open water outside the harbor. After careful consideration of this plan, the British commanders decided that it was impracticable. The submarines were therefore blown up.

There has been a good deal of discussion, since the war began, regarding the most favorable season for submarine activity. Opinions have differed on this question. At present, naval opinion in Washington seems to be that the season makes little difference. The smoother water and the longer daylight of summer are an advantage during that season, but these may be offset by the better opportunity which the submarines have, during the long winter nights, to come to the surface to recharge their batteries, to rest their crews, and to make long trips unsubmerged, thereby increasing their effective area.

It was not to be expected that there would be any considerable activity in the Trentino sector of the Italian front until well along into the spring. The deep winter snows of that rugged mountainous region are unlikely, under ordinary conditions, to melt sufficiently to make active campaigning possible until May, or perhaps even early June. Heavy snowfalls were reported early in March. On March 18 an Associated Press despatch noted that "the snow along the mountain fronts has been reduced considerably by mild weather recently, but

the amount remaining is still sufficient to retard extensive operations." On the Piave front spring freshets made the stream "too wide and deep for crossing by considerable bodies of troops." Late in April (28th and 30th) severe winter weather prevailed along the Italian front, heavy snowfalls (6 feet deep in places) and "blizzards" being reported in the Alpine sector, and intense cold on the Venetian plain. Several days of torrential rain had swollen the Piave and Adige Rivers. Such conditions made an Austrian offensive impossible, the snow having obstructed the roads, and rendering the movement of the enemy troops very slow and difficult.

> The delay caused by the snow and the general atmospheric conditions permits the Italians to complete their defensive works, and add to their reserves of guns and ammunition.[2]

Shortly before the middle of May (10th) the Italians began the spring campaign, after a long period of winter inactivity, by capturing the dominating position of Monte Corno, a summit reported as 6,000 feet high, and still snow-covered. The topography and the snow presented great difficulties to the Italian troops, but the enemy was taken by surprise and a considerable number of Austrians were made prisoners. The advance of spring, accompanied by the melting of the snows and more favorable weather, led to the expectation, on the part of the Italians, of a speedy inauguration of the expected Austrian offensive. A Rome despatch, dated May 20, was as follows:

> The only obstacle which prevents an enemy attack immediately is the weather, which this year continues to be rainy, foggy, and even cold in some of the higher regions, with continual hailstorms. But the weather is becoming undeniably milder. The snow is beginning to melt, while avalanches often bury the emplacements and the huts which have been excavated.

During the last days of May, the Italians won a brilliant victory in the Tonale region, some 12,000 feet above sea level, northwest of Trent. The ground was still covered with snow, and the fighting was among glaciers.

In Palestine the British continued their advance. The weather was still on the whole favorable for military operations, the heat and drought of the summer not yet having really set in. An interesting illustration of the part played by local meteorological phenomena occurred on March 16, 78 miles northwest of Medina, when, under cover of a sandstorm, a company of the Turkish Camel Corps was surprised and destroyed.

[2] Rome despatch to Italian Embassy in Washington, May 4.

Both duststorm and Camel Corps bear witness to the climate of the region in which this incident took place.

In Mesopotamia there has been considerable activity. After months of preparation, the British have lately been advancing northward along both the Tigris and the Euphrates Rivers, the objective being Mosul, an important Turkish base. The hottest and driest season of the year is rapidly approaching, both in Palestine and in Mesopotamia, and major operations are not likely to be carried on in either country unless there is absolute necessity for the continuance of an active campaign. A report dated May 7 mentioned a heavy rain near Kerkuk (Mesopotamia). Such rainfalls are improbable again until the next winter rainy season sets in, after the almost intolerable heat of the summer and autumn is over. Major-Gen. Sir Frederick Maurice, in his war summary of May 24, said that

> Not the least of the advantages we have gained by our recent efforts is that we occupied a portion of the Persian foothills, which give a healthier country for the summering of our troops than the plains of Bagdad afford.

At sea, the weather factor has played a considerable part. In the daring raid on the German naval bases at Zeebrugge and Ostend (April 22), Admiral Keyes, according to the reports, waited for "certain conditions of wind and weather" before he gave orders for his fleet to cross the Channel. What the British wanted was a weather type which should combine an ordinary ocean fog with winds favorable for the use of a smoke curtain for purposes of concealment. The British vessels advanced under a dense smoke screen, aided later by a fog. Aerial work was necessarily interfered with. A clear and concise press report of the operations is as follows:

> The losses of the Zeebrugge raiders were due almost entirely to a shift of the wind, which prevented the complete success of the smoke screen. Fortunately, the wind held in the right direction long enough to enable the *Vindictive* and her consorts to approach the mole, but changed and dissipated the screen as the men landed. This enabled the Germans to find targets.
>
> At Ostend the shift of the wind came a little earlier and upset the plans of attack. Small craft with smoke apparatus ran in according to program and set up a screen. Then they lit two large flares to mark the entrance of the harbor for the concrete cruisers. Unfortunately, before these could get up, the screen was blown away and the German gunfire quickly destroyed the flares. This left our cruisers with nothing to guide them, and though they tried to proceed by guesswork under heavy fire, these gallant efforts were in vain.

According to Sir Eric Geddes, the difficulties at Ostend

were "considerably increased by mist, rain and low visibility, and the consequent absence of aerial cooperation." The Italian naval exploit at Pola, which resulted in the destruction of an Austrian dreadnaught, was favored by a very dark night, and an offshore wind, which prevented the sounds of preparation from being carried landward.

The war in the air is being carried on with steadily increasing intensity. Aviators are flying in weather conditions—rain and snow storms; gales and mists—which were only very lately regarded as prohibitive. As aerial warfare continues on the western front, the disadvantage under which the Allied flyers labor because of the prevailing westerly winds are receiving more and more emphasis. As a well-known aviator has recently expressed it, "if an airman ever wishes for a favorable wind it is when he is breaking for home. . . . These westerly gales were one of the worst things we had to contend with at the Front. They made it very easy for us to dash into enemy territory, but it was a very different story when we started for home and had to combat the tempest." In connection with general air raids, several points are worth noting. On March 11 nine squadrons of German airplanes attacked Paris during a fog, which "was thick enough to cause the general belief that there was little chance that the Germans would attempt an air raid." It may very likely have been for this reason that these weather conditions were selected. A German raid on Hull and its vicinity on March 13 was also "completely unexpected. The night was dark, and a slight drizzle was falling." This raid, and others, have shown that the German aviators no longer depend on moonlight. Early in March, the Germans made their first night air-raid on London when there was no moon. The stars were out, however, and there was little wind. On May 19 another raid was made on a very clear night, when the moon was shining. On April 12 a German air raid on Paris was made on a "still, dark night, of the sort most favorable for an aerial attack, and a raid was generally expected." And on May 21, during another raid, the night was clear and calm, with a brilliant moon, "ideal for an aerial attack."

In connection with the work of the German army meteorological service, it has, since the beginning of the war, been a matter of some interest to know how the enemy obtains the observations, especially from the western coast of Ireland, which are very necessary in constructing weather maps and in making forecasts. Captured documents show that their meteorological reports are fairly complete, despite the fact that no pub-

lication of weather data or forecasts is permitted in English newspapers. An English meteorological expert declares that the answer to the question is not through any system of spies and land wireless, but that the data are obtained from observations taken by submarines. He thinks that a submarine working off the western Irish coast is detailed to send weather reports to Germany by relays through the wireless apparatus working around the British Isles.

In the African war zone, where so many political changes have taken place but from which so little direct information has come, the spring months have witnessed an advance of the allied troops on the remnants of the German forces which escaped from German East Africa to Portuguese East Africa. An official despatch dated London, April 11, says:

> In Portuguese Nyassaland, despite the difficulties caused by heavy rains and flooded rivers, our columns from the coast and from Lake Nyassa are approaching Medo and Msalu, respectively, and their advanced troops are in contact with those of the main enemy forces concentrated in these localities.

A later report (April 27) from the British War Office stated:

> Since April 17 the convergent advance of General Northey and General Edwards's troops has proceeded under better weather conditions. The main enemy force is in the vicinity of Namungo. British and Portuguese troops are moving in the direction of Msalu River, while further south other British and Portuguese columns have been disposed north and south of the River Lurio.

PLANT AND ANIMAL LIFE IN THE PURIFICATION OF A POLLUTED STREAM

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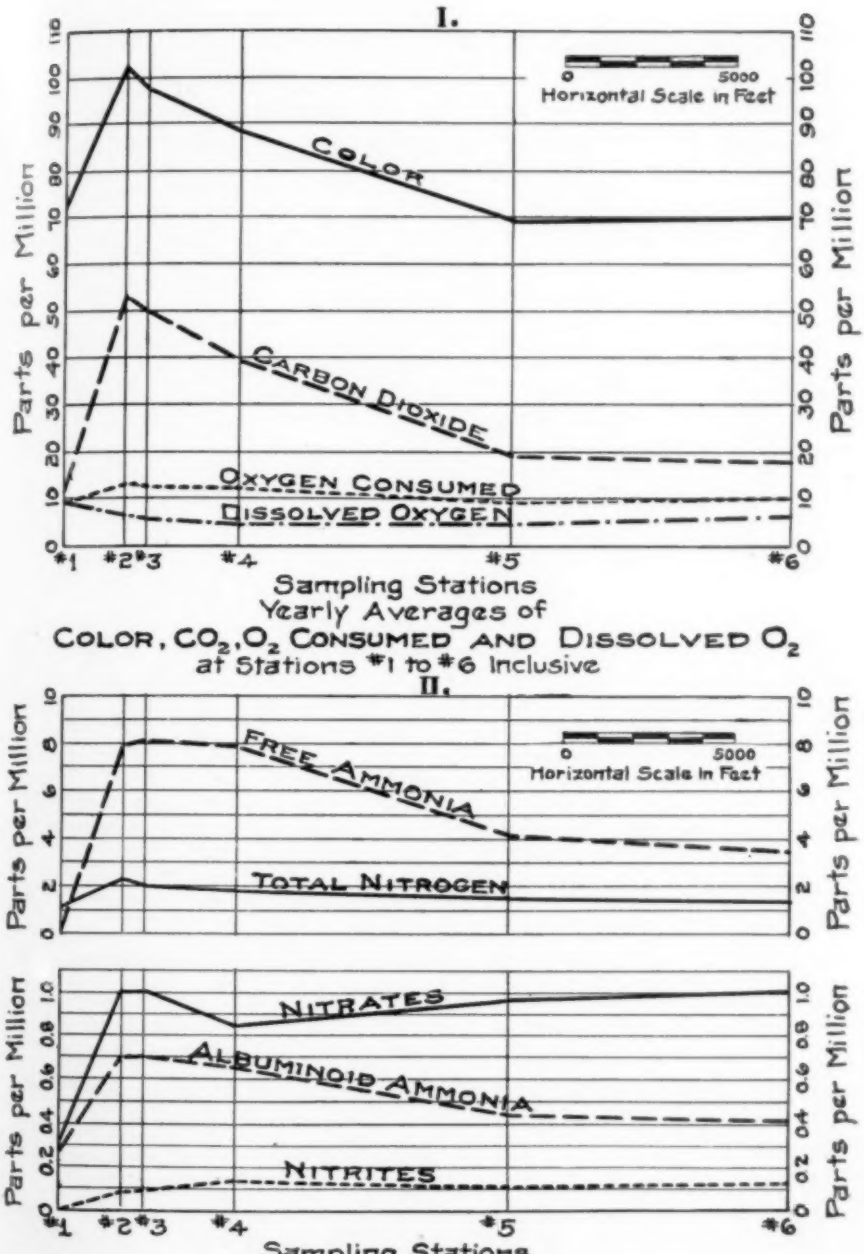
RIVERS and other streams have always been resorted to by man for the disposal of his wastes. And yet unless greatly overtaxed they remain fairly clean. The problem here raised reminds one of that wonder of the ancients that all the rivers run into the sea and yet the sea is not full. What becomes of all the dirt and the street-wash and the sewage that find their way into our streams?

The "self-purification" of streams is an old and captivating phrase graphically describing a process which is patent even to a superficial observer. On the Merrimac, for example, Concord, Manchester and Nashua, important cities of New Hampshire, poured all their sewage into the noble river flowing past their doors, while Lowell, Mass., only sixteen miles below Nashua, did not hesitate to drink the water now again clear and bright, which reached the intake pipe of its city water works. More wonderful still, Lawrence, only nine miles below Lowell, drank directly from the same stream after the sewage of the 80,000 inhabitants of that city had been added to it. Alternating pollution and purification is the common characteristic of streams. The mechanism of pollution is obvious, but how about the process of purification? It was to throw further light if possible upon the self-cleansing of polluted streams, that the Sanitary Research Laboratory of the Massachusetts Institute of Technology carried on for two years an investigation of a small stream polluted by a relatively large quantity of partially purified sewage effluent which reaches it from slow sand filters.

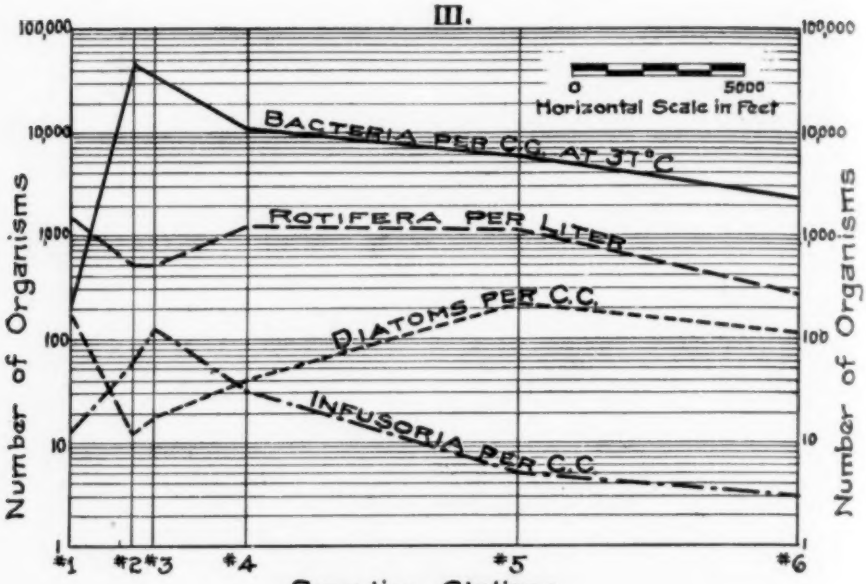
Whence comes the water of a normal brook or river? The answer is, partly from the atmosphere as rain or snow, partly from the earth's surface through tributary rills or brooklets, but largely from the ground upon which it has fallen, through which it is filtered, and from which it arrives comparatively pure from all but the smallest suspended matters. This ground water, however, does contain dissolved gases and salts together



Yearly Averages of
COLOR, CO_2, O_2 CONSUMED AND DISSOLVED O_2
at Stations #1 to #6 Inclusive

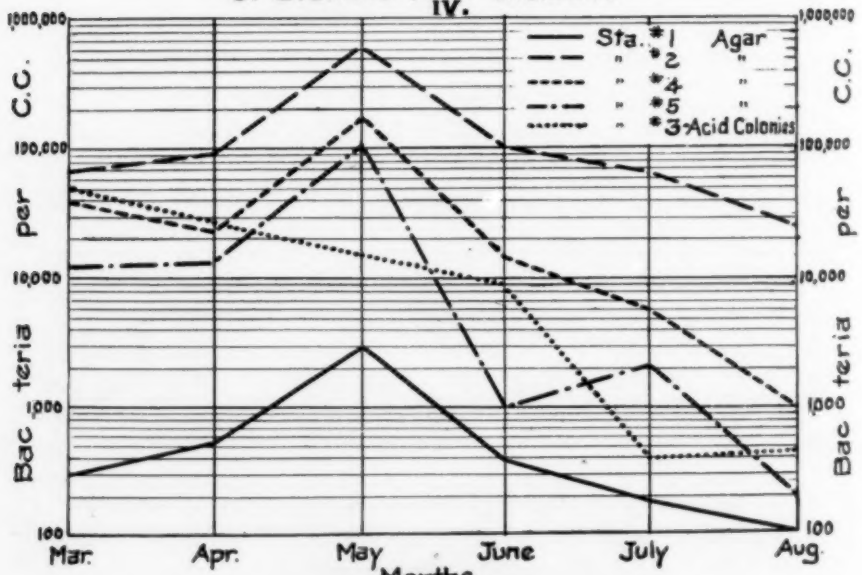
Yearly Averages of
NITROGEN AS FREE NH_3, ALBUMINOID NH_3, NITRITES, NITRATES AND TOTAL N at Stations #1 to #6 Inclusive

III.



Yearly Averages of
ORGANISMS
at Stations *1 to 6 Inclusive

IV.



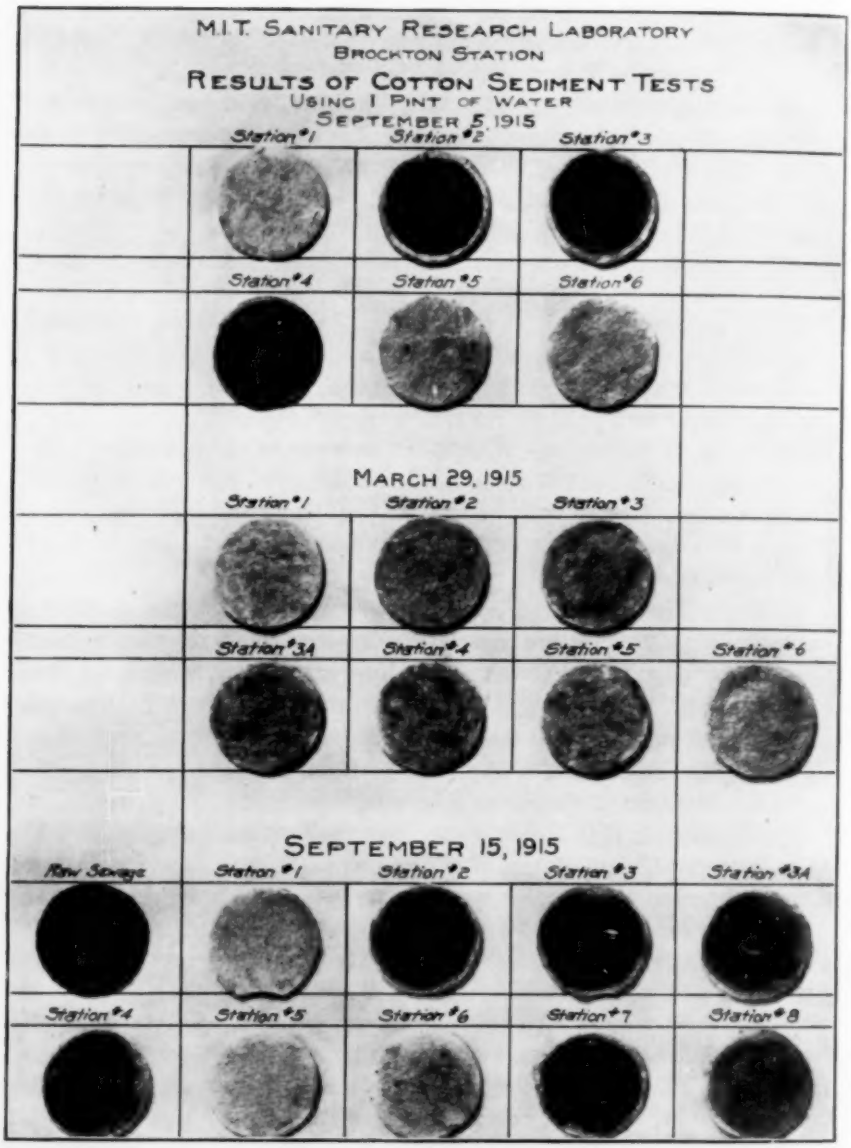
Average Monthly

TOTAL BACTERIA AND ACID COLONIES ON AGAR
for the 6 Months ending Sept. 1, 1915

with a small amount of organic matter. On the other hand, water which arrives after a journey overland generally brings with it more or less dirt and débris. In the stream under consideration, contributions of a large volume were received from the underdrains of artificial sand fields upon whose surface had been poured the Brockton city sewage. A strange and heavy burden was thus laid upon a quiet stream hitherto unpolluted. The first thing that happened was a mixture of two very unlike waters, that of the brook and that of the underdrains. This little creek of pure water with a summer flow of only one half million gallons per day, bright, clear, sweet smelling, containing little carbonic acid and few bacteria, poor in nitrates, poor in organic matter but rich in dissolved oxygen, becomes charged with a daily flow of two million gallons of water poor in oxygen, laden with carbon dioxide, burdened with bacteria, rich in plant foods, malodorous and full of broken-down organic compounds of uncertain composition and dubious ancestry. Forthwith various fermentations and other mysterious biological operations begin.

Above the Brockton sewage beds the brook has a clean, sandy or peaty bottom and the usual variety of plants and animals to be found in a clear New England brook. As the first effluent drains pour in their contribution, the bottom of the stream in summer becomes brown with a gelatinous growth of the iron bacterium, *Crenothrix*, which may occur to a depth of two or three inches over the whole bed of the stream. As the proportion of polluted water is greater, the bottom becomes black with organic material which has settled out from solution and suspension together with silica and other inorganic material forming a sort of "pollution carpet" or "false bottom" in which biological activity is very intense, and where chemical changes are rapidly taking place. There are many bacteria in the polluted water but the number in this bottom mud is much greater, while protozoa, rotifers, worms and insect larvæ also abound. The sides of the stream in many places are gray with furry growths of the colonial protozoa, *Carchesium*.

Throughout the regions where this false bottom is present —and it extends for three fourths of a mile below the filter beds —there may be seen large patches of the red worm, *Tubifex tubifex*. The countless individuals making up these colonies of bristle worms, so typical of pollution, remain with their heads in their burrows, the tails, like a red flag of pollution, waving in the water above them in search of oxygen. They quickly disappear into their holes at the slightest disturbance



in the water such as might be made by the approach of a fish, for it must be noted that higher animals are not driven away by the amount of pollution here present. Minnows are frequently seen in this part of the stream, often nibbling at the furry growths of *Carchesium* mentioned above. In the spring suckers are to be found here and occasionally brook trout or brook pickerel make their appearance. They are, however,

more abundant in the stream below or above the area of greatest pollution. Snapping turtles, water snakes and the green frog, *Rana clamata*, are frequently seen and the valley of the brook contains an abundance of bird life including wild ducks, crows, robins, bobolinks, blackbirds, grackles and sparrows.

By far the most conspicuous of the insect larvæ in this region of abundant food material is the "blood worm" or larva of the midge, *Chironomus decorus*, which is one of the most efficient scavengers of this type of stream bottom. The mature insect is about the size of the mosquito and in appearance bears a close resemblance, although fortunately its habits are much less objectionable. In this species there is no irresistible impulse to gorge itself with blood and usually the mature form never feeds. The eggs are laid in rows in a gelatinous sack which is attached to some object at the surface of flowing water. Each sack contains 1,200 to 1,500 eggs and so numerous are they that a partly submerged railroad tie was found to furnish a hatching place for over 300,000 midges. The larva is hatched as a white wiggler nearly 1 mm. long which soon settles to the bottom and spends most of its time in eating, growing in three or four days to one fourth of an inch in length and taking on a pink color which soon develops into a brilliant red. At this time the larva begins to make a case for itself by gluing together the material about it with a gelatinous substance from its salivary glands. In many places on the muddy and soft stream bottom, these little mounds, each with an opening at the top, number four or five hundred per square foot. A 30 c.c. sample of bottom mud collected to a depth of 2″ in August, 1914, contained 130 of these larvæ. The larval period lasts from several days to several weeks depending upon the temperature, then follows a brief pupal stage in which the insect undergoes metamorphosis and at the end of which the pupa, which is also active, rises to the surface. The pupal case is split along the back, the imago emerges, rests for a minute on the floating pupal case and then flies away. If the good fortune by which it escaped fish and predatory insects continues and it is able to avoid the numerous dragon flies and other enemies for a day or two it reproduces and dies. From the omnivorous habits of the larvæ, their value as food for fish, and the number of mature insects which leave the water entirely, it is obvious that *Chironomus* is an important factor in the removal of organic matter.

Of the great variety of insect larvæ found in this region, mention may here be made of only one other, the larva of the

Midsummer view of the Stream from near Station 2. This shows the part of the stream which is receiving pollution from the sand sewage-filter beds. Note that the stream is somewhat swifter here and the vegetation on the banks is most luxuriant. From photo taken July 21, 1915.

club-footed gnat, *Ptychoptera clavipes*. These brown air-breathing larvæ have the same habitat as do the blood worms, although they are not as numerous or as important from the standpoint of stream purification. The first generation appears about the middle of March and from that time they are abundant until late fall. Both the larval and pupal stages are

A corresponding view on January 26, 1916, showing where some of the sewage effluent drains enter the stream, as well as the appearance of the banks in winter and the increased volume of water.

to be found in relatively shallow and quiet water with the elongated breathing tubes reaching to the surface.

It must not be concluded that plant life is absent from this region. To be sure the variety of higher plants disappears at the point of pollution, but one by one these plants reappear as the pollution is reduced, so that the region three quarters of a mile below the filter beds contains the rankest growth of water plants to be found in any part of the stream. Throughout the summer and until late fall they choke the stream in this region, reducing the velocity of the current, furnishing shelter to a wide variety of smaller animal and plant forms, supplying oxygen to the stream, and acting as a contact filter upon which may settle out suspended and colloidal substances. So efficient is this filter that attempts to measure the velocity of stream flow by adding a coal-tar dye to the water were completely frustrated.

In the masses of these plants as well as upon the stream bottom, there may be found innumerable snails and small crustacea. Upon one occasion fifty snails were gathered by one scoop with the two hands at a point one half a mile below the filter beds. The Isopod, *Asellus*, which is present in all parts of the stream, is so abundant here that as many as twenty may often be seen upon a square foot of the stream bottom, while a handful of water grass or pond weed may contain twice this number. Smaller crustacea, the water fleas, are also abundant, their presence being correlated with that of the simple green algæ. In a pool a short distance below the filter beds the water is green in summer with *Chlamydomonas* and *Euglena*. At such times the Daphnia-like form, *Simocephalus*, is so abundant that even the surface water contains more than one thousand per liter. In all these the digestive tract is filled with the green flagellates which appear to constitute the chief food. Special chemical tests show that there is a daily seesaw between the oxygen dissolved in the water and CO_2 under these conditions. The former goes up continually through the daytime under the stimulation of sunlight upon the chlorophyll-bearing flagellates, and the latter goes up continually through the night because of animal activity, the total volume of oxygen in the two gases remaining practically constant. In the fall when these water fleas are most abundant myriads of *Hydra* are found throughout the higher plants.

This in brief is the picture of the stream as we find it through the summer months, when it teems with an activity so

This view, looking north near Station 4, July 21, 1915, shows how completely the higher aquatic plants fill this part of the stream in summer. Station 4 is located at a point in the very center of the picture.

intense that the term "living earth" as applied to the bottom of a polluted stream takes on a new significance. We are better able to understand the intensity of this biological digestive process when we add to our picture of these larger forms a measure of the microscopic organisms to be found in the water and some measure of the chemical process which is here carried on. The accompanying diagrams show the quantity of chemical substances and microorganisms in the water

A corresponding view, January 26, 1916, shows how differently this same region appears under winter conditions and high stream flow.

at various points, Station 1 being on the unpolluted stream above the filter beds and Station 2 at the point of greatest pollution. The distance from Station 2 to Station 3 is 980 ft., to 3a it is 2,000 ft., to 4 it is 3,650 ft., to 5 it is 11,580 ft. and to 6 it is 19,700 ft. The discussion thus far has been confined to the area between Stations 2 and 4.

Chemical changes are also graphically shown. By careful measurements and computations from our chemical analyses, it was found that in summer the average reduction in total organic nitrogen, as measured by the Kjeldahl process, in the first three quarters of a mile below Station 2 was as great as 39 lbs. per day. If we were to consider this upon the basis of protein consumption, it would mean that the equivalent of more than 150 lbs. of beefsteak is digested daily by the small stream in traveling this distance.

Standard chemical and bacteriological methods were used in making the weekly analysis from which the averages here graphically represented were computed but the method of securing the biological data may require some explanation. It was soon learned that quantitative determinations of microorganisms according to the Sedgwick-Rafter process were of little value if the samples were collected from the surface water. The forms thus found were the floating organisms which had been brought down from up the stream instead of the forms "working" at that point. Accordingly the bottom of the brook was disturbed across its entire breadth by means of a garden rake and a sample from the clouded water thus produced collected in a 500 c.c. wide-mouthed bottle at a depth of 6 inches below the surface. Naturally these samples were somewhat widely varying but since they were collected near the surface they can not overestimate the number of organisms and the graphs made from the yearly average really show the effect of pollution upon the smaller plant and animal life of the stream.

A word should be said about this region in winer. Early in December the higher plants disappear. The volume of the stream increases to ten or occasionally twenty million gallons per day, the nitrification of the sewage in passing through the sand filters is less complete and the whole stream presents a markedly different appearance, as may be seen from the accompanying photographs. At about this time, the water mould, *Leptomitus*, appears near the effluent drains and within a couple of weeks covers the bottom and sides of the stream throughout the first three quarters of a mile of its flow. There are literally tons of the mould present, which soon changes

from its fleecy white appearance to a dirty gray color because of the accumulation of dirt and organic matter which has settled upon it from the polluted water. This is a new pollution carpet which nature has spread over the bottom of the swollen stream for the winter season. Among the threads of the mould intense biological activity takes place. As many as 400,000 bacteria per c.c. are present and the protozoa (*Colpidium, Chlamydomonas, Euglena viridis, Euplotes*) total 125 per c.c., while *Asellus*, midge larvæ and naid worms are abundant. The stream overflows the meadows, and over these acres of flooded marsh land, *Leptomitus* occurs in abundance. The water shows little or no improvement in this region in winter beyond that directly due to dilution, and because *Leptomitus* is continually breaking down and flowing along with the current, some samples in early spring show even more organic matter three quarters of a mile below the filter beds. At this season the meadows become covered with filamentous green algæ (*Conferva* and *Spirogyra*) which grow with *Leptomitus* and gradually supplant it. The fungus is figuratively driven up the stream and into the mouths of the effluent drains to emerge again the following winter. The algæ appear first at some distance down the stream and slowly work their way toward the point of pollution. As the water subsides, these growths are left as a black deposit on the soil resembling sewage scum in appearance. With the arrival of warm weather the filter beds become more efficient, the zone of greater pollution which is measured by the presence of *Leptomitus* is shortened, the biological activity of the stream increases and summer conditions return.

We have as yet considered only the first three quarters of a mile of the polluted stream. At this point a small effluent stream joins the one under observation and during the summer months the self-purification mentioned above is so important and complete that below this point, from a biological point of view, the stream is comparatively normal except perhaps that more plants are present because of the greater amount of plant food. The false bottom no longer persists and to the casual observer nothing unusual would be noted either in the water or plant and animal life.

Samples were taken regularly at points one mile and two miles below the juncture of the two streams with results which appear in part in the accompanying diagrams. The chemical studies reveal the presence of distinct pollution, but it is clear that biological activities are less intense and that, because of

this, chemical changes are much slower. In the winter when the purification is much slower and depends largely upon the factor of dilution, these lower regions of the stream are in a worse condition. But *Leptomitus* is never found growing below the juncture of the two streams except for such small masses as may be carried down by the current and persist temporarily. The chief interest, therefore, attaches itself to the more intense digestive process above described, showing how nature lends her assistance to the sanitary engineer, enabling him to carry the sewage effluent of the shoe manufacturing city of 65,000 people into a tiny brook only six or eight feet wide.

The complete details and conclusions of a two years' study are contained in the original report, but some of the general facts, without special reference to quantitative results, may be briefly stated. It is obvious that the biological factors of stream purification are much more important than the strictly chemical and physical factors. The activities during the summer months were sufficiently intense to take care of the burden being placed upon the stream at that time and also to remove the load of pollution which the winter had left. Certain organisms are characteristic of an unpolluted stream. Others are characteristic of pollution and by their presence and numbers indicate the intensity of biological activity. Some forms like rotifers and certain green algæ may be present in either polluted or unpolluted water and their correlation with each other and various plants and animals must be understood to appreciate their significance.

The organic matter, introduced with a sewage effluent, results in the increase of organisms in a cycle beginning with bacteria and ending with the higher forms, each type of animal appearing with a definite food supply. A comparison of this investigation with studies made upon other streams and grosser types of pollution shows that the smaller, shallower and more nearly stagnant the body of water with which the pollution is mixed and the more nitrified and clarified the effluent, the more rapid is the succession of zones of higher animal life and the more complete the process of purification.

EVOLUTION BY MUTATION

By Professor T. H. MORGAN

COLUMBIA UNIVERSITY

STUDENTS of Mendelian heredity have shown during the last seventeen years great reluctance in bringing their results to the bar of the evolutionary theory. They have hesitated, I think, because they felt that they had in hand a body of well-established information in regard to heredity which they did not want to compromise by applying to it the kind of procedure that in other fields of evolution is, even to-day, taken seriously.

The pressure on the Mendelians has come, then, from without rather than from within. But the Mutationists and the Mendelians are twin brothers because they appeal to the same scientific procedure, viz., analytical experimentation, and because both study the process of discontinuous variation. It has been more than insinuated, more than once and from more than one quarter, that the kind of unit characters that the Mendelians are studying has nothing to do with the kind of characters that evolution has to deal with. On what kind of evidence is this assertion based? Evidently it has its roots in the notorious fact that the Mutationist pays very little attention to the kind of a character that he uses in his work; the more extreme, the better, because he can the more easily identify it. But *he* knows (although the systematist tries to make it appear that he does not know) that between such extreme and even bizarre characters, and those that systematists themselves use for diagnostic purposes there is every gradation conceivable.

Species as Groups of Genes

One of the most interesting ideas that De Vries brought forward in his mutation theory was that groups of "small species" or of varieties are made up of many common genes and differ in a relatively small number of genes. The genetic analysis of a group of smaller species would consist in finding out how the different genes were distributed amongst the members of this group. Phylogenetic relationship comes to have a different significance from the traditional relationship expressed in the descent theory; but this point of view is so novel

that it has not yet received the recognition which we may expect that it will obtain in the future when relationship by common descent will be recognized as of minor importance as compared with relationship due to a community of genes while differences are due to different combinations of genes.

If related species have many genes in common they may be expected to produce at times the same mutants. In fact, it is not at all uncommon to find even in Mendelian literature such forms as albinos spoken of as though they represent the same mutation wherever it arises. Attractive as such a view appears, experience has shown that it is very unsafe to judge as to the nature of the mutation from the appearance of the character alone. Two different white-flowered races of sweet peas are known which give the wild purple-flowering pea when crossed, showing that they represent different mutations. Similarly, at least two recessive white races of fowls are known, as well as a third dominant white race. Three independent mutations have produced white birds. Whether albino mice, rats, rabbits, squirrels and guinea pigs have arisen through a mutation in the same common gene can not be determined because they can not be crossed to each other. When we consider that many factors may combine to produce a given pigmented animal and that a change in any one of them may affect the end result, it will be evident that the expectation would be against rather than for the conclusion that the same gene had changed in all cases. Only when it could be shown that a particular gene of the complex is more likely to change in a given direction than other genes of the complex would this interpretation become plausible.

There is some evidence in *Drosophila melanogaster* showing that the same mutation to white eyes has occurred several times, and the additional and all-important proof obtained that it is the same locus that has produced the white-eyed mutant. This may appear to give some slight support to the view that albino mutants appearing in other related species may be due to the same mutative changes but without additional evidence this conclusion is problematical.

In the mammals melanic individuals have been frequently described, but there is no direct evidence to show that they are due to the same change. In the roof rat there is a black type that is dominant to the gray of this race, while the black type of the Norway rat is recessive to the gray of that race. It seems probable that they are different mutations but not necessarily so.

Yellow in the mouse is dominant and lethal; two races of yellow rats are known, both recessive forms. The relation of yellow to black in mice is different from the relation of either of the yellows to black in the Norway rat. If the blacks are the same mutant the yellows are different, if either yellow of the rat is the same as the yellow of the mouse the blacks must be different, etc.

The uncertainty of reaching any conclusion in regard to the nature of the mutation from the appearance of the character of the mutant is excellently illustrated in such a group of mutants as that of the fruit fly, where a considerable number of cases are known in which mutants that are almost indistinguishable externally have been shown to be due to mutations in different parts of the germ plasm. There are five kinds of black mutants, three or more yellows and several eye colors that are practically indistinguishable. The evidence showing their difference is based on the results of crossing, where, as a rule (except, for example, for complete or incomplete dominants), reversion to the wild type occurs. In addition, the localization of the gene causing the modification shows them to be different.

The method of localizing genes opens up an opportunity for obtaining evidence in regard to like-mutants in related species that can not be crossed and a step forward in this direction has been taken by C. W. Metz for other species of the genus *Drosophila*. In a species, *D. virilis*, he has had 12 mutants appear and these fall into three groups of linked genes. Three of them, yellow, forked and confluent, resemble externally characters of *D. melanogaster*. Yellow and forked are sex-linked and look like the same characters in *melanogaster*. Confluent is like a second chromosome character of the same name in *melanogaster* in three respects: first, the structural similarity, second, that the character is dominant in both forms, and third, that it is, Metz thinks, lethal in homozygous state. The terminal position of yellow and the large amount of crossing over with forked are roughly speaking the same in both.

Even in this case further work is needed, first, because within the same species the occurrence of similar-looking characters due to different factors is known, *i. e.*, there are two genes for yellow color (yellow and lemon) in the first chromosome and in the same part of that chromosome, and second, because it is not to be expected that the number of crossovers would be identically the same between the same loci in different species, since marked variations are known within a single species.

Unless such species can be crossed the only convincing evidence that we can hope to get will be to establish the same *linear order* in the chromosome for several genes whose characters appear to be the same or similar.

Is the Direction of Mutation given in the Constitution of the Gene?

Whether we think of the gene as a complex molecule or as a quantity of material holding together through cell generations, it seems plausible that its mutations will be conditioned by its nature. If it is a molecule these changes may be strictly limited, numerous though the possible changes may be; but if it is only a definite "quantity" of something, the amount of its increase (plus) or decrease (minus) might *seem* less restricted, since any amount of increase or decrease might appear possible. We are left to pure speculation. Do the observed facts of mutation furnish any data on which to base even a guess? As has been said, we are scarcely warranted in drawing any conclusions from the nature of the character as to the nature of the gene, because, *a priori* at least, any change in the gene might cause an increased or decreased effect on the characters chiefly influenced by that gene. If, however, we boldly disregard this danger it may seem plausible that the building up of a complex molecule would be more likely to have a more limited range of possibilities than the rearrangement or degradation of that molecule. If this could be made probable, progress, in the sense of greater genic complications, would seem less likely to occur than degeneration. As hinted before, the recessive nature of the great majority of observed mutations might seem to harmonize better with this view. But we are too ignorant concerning these questions to make a discussion of them profitable.

Is the outlook any brighter if we take only quantitative changes in the gene as a basis for speculation? If the gene varies about a modal amount that accounts in part (for the environment also comes in here to complicate the effects on the character) for the degree of development of the character, it would seem to follow that the more the amount of the gene, the greater its effect on the character, and the less its amount, the smaller its effect. If we go further and suppose that nearly the maximum amount of a gene possible under the physiological conditions of the cell is more likely to be that maintained by selection in the wild species, it would follow that decreases in this amount are more likely to happen than increases, hence the

more frequent occurrence of mutation by loss or recessive mutations. The facts concerning allelomorphic series indicate that the amounts "lost" (if the change is of this sort) are not progressive, but, so to speak, haphazard, and this, too, is consistent with the idea that such recessive changes may involve any amount of loss. Contrariwise, if the upper range in amount is near the maximum possible for the cell physiology, positive advance might take place more gradually and progressively, giving changes like those of orthogenesis claimed by paleontologists and some systematists to be the way in which species advance. This hypothetical situation is, however, uncertain in a high degree the moment one realizes that changes up and down of a character appear more often brought about now by one, now by another gene, rather than of the principal one, *i. e.*, the one on which, owing to a mutation, especial attention is focused. In fact, at present it is not even probable that progressive character changes are generally due to progress in the principal gene (except in multiple allelomorphs) and there is verifiable evidence in the only cases where really crucial evidence has been obtained that the changes are due to other genes.

It is true that when writers have brought forward evidence of continuous and progressive change in a character they have not concerned themselves with the analysis of the change in the germ plasm that has brought it about—in fact, in most of these cases the possibility of advance in a principal gene or of advance through modifying genes had not been appreciated or even understood. Paleontologists who have in the main been the strong advocates of orthogenesis have based their conclusions on the observed advances in a character in the same series and in "parallel" series. They overlook the fact that to-day there is experimental evidence demonstrating that variations as small even as those they record have been shown to rest on mutational stages. If the progress has been in the direction of adaptation, natural selection of small mutant differences will completely cover their findings. If it is claimed that in some of these cases the orthogenetic series is not in the line of adaptive advance, the burden of proof lies heavily on their shoulders. Moreover, the fact that recent work has made clear that genes generally have more than a single effect on the organization opens wide the door of suspicion, for the observed morphological progress might be a by-product of influences that have other and important, though unseen, effects. In a word, an orthogenetic series of changes does not in itself without a closer analysis than has as yet been furnished, establish that an *innate*

principle, urge, vis-a-tergo, or driving "force" is causing the successive moves. The genetic evidence from multiple factors must create at least a strong suspicion against the "will to believe" in the mystic sentiments for which these terms always stand. That a progressive series of advances in a gene might take place with a consequent advance in the many characters involved is *thinkable,* especially if it could be shown that environmental changes cause parallel progress in the gene and this in turn in the character. How *probable* this is the reader must decide for himself in the light of the very clear evidence that each character is affected by changes in many genes differently located in the germ plasm and that it is not a progressive change in one gene that makes selection possible but changes in any one of many genes.

Chance Mutation and Natural Selection

The mutation process rests its argument for evolution on the view that among the possible changes in the genes, some combinations may happen to produce characters that are better suited to some place in the external world than were the original characters. Apparently this appeal to chance, like Darwin's appeal, has offended some sentimental adherents of the doctrine of organic evolution, because it has seemed to them inconceivable that chance could ever bring about the assembling of such an intricate piece of machinery as a highly complex organism. The attempt to mitigate the rude shock of the appeal to chance was made by Darwin by pointing out that evolution had been gradual and that the assemblage has not taken place out of chaos, but each stage has been built up on one a little less complex than the preceding one. Nevertheless, the fact remains that persistent efforts continue to be made from time to time to introduce into the theory of evolution some sort of directive agent. The Lamarckian theory has tried to bring about a more immediate relation between the organism and its environment of such a kind that the adaptive change that appears in the body as a result of a reaction between the environment and the animal or plant is reflected into the germ plasm. Bergson has cut the knot by postulating an innate adaptive responsiveness of the animal to every critical situation that calls out a response. The adherents of orthogenesis appeal, apparently—in so far as they commit themselves—to some sort of innate principle that causes advance in complexity along one line and they seem to hint at

times even along directed lines of adaptation. Still more elusive are vague appeals made to some unknown principle—some sort of Mystical Element resident in living material and peculiar to it that is *Responsible* for evolution.

We are not concerned with any of these so-called "Laws" or Principles or Agents, but there is a relation between chance and evolution shown by living things that has been largely neglected, or at least vaguely referred to, even by natural selectionists, that is of fundamental importance when evolution is treated as a phenomenon of chance.

This relation may be stated in a general way as follows: Starting at any stage, the degree of development of any character increases the probability of further stages in the same direction. The relation can better be illustrated by specific cases. The familiar example of tossing pennies will serve. If I have thrown heads five times in succession, the chance that at the next toss of a penny I may make a run to six heads is greater than if I tossed six pennies at once. Not, of course, because five separate tosses of heads will increase the likelihood that at the next toss a head rather than a tail will turn up, but only that the chances are equal for a head or a tail, so that I have equal chances of increasing the run to six by that throw, while if I tossed six pennies at once the chances of getting six heads in one throw are only once in 64 times.

Similar illustrations in the case of animals and plants bring out the same point. If a race of men averages 5 feet 10 inches, and *on the average* mutations are not more than two inches above or below the racial average, the chance of a mutant individual appearing that is 6 feet tall is greater than in a race of 5-foot men. If increase in height is an advantage the taller race has a better chance than the smaller one. This statement does not exclude the possibility that a short race might *happen* to beat out in increment of growth a taller race, for it might more often mutate; but chance favors the tall. In this sense evolution is more likely to take place along the lines already followed, if further advantage is to be found in that direction.

A rolling snowball that already weighs 10 pounds is more likely to reach 15 pounds than is another that has just begun to roll. The chance that a monkey could change into a man is far greater than that ameba could make the transition. The monkey has accumulated, so to speak, so many of the things that go to make up a man that his chance of reaching that goal is vastly greater than ameba's.

There is also a peculiarity of animals and plants that assists

greatly towards progress along lines already started. The individual multiplies itself, and a new mutant character that is advantageous becomes established in a large number of individuals, or even in all individuals of the race. The number of individuals increases the chance of a new random mutation along the path already taken. It is true that the number also increases the chance of a random variation in the opposite direction but as this, by hypothesis, is the less advantageous direction it will fail to establish itself in numbers.

Artificial Selection and Mutation

Darwin built up his evidence for natural selection, and even for evolution, on the *artificial* selection of *variations* of animals and plants under domestication. It is in this field that the student of Mendelism revels. Almost without exception he finds that the domestic races of animals and plants are built up by mutational differences. It is this evidence that to-day is a hundredfold stronger for the theory of evolution than it was in Darwin's time. Shall we turn our back on it now when the evidence is clearer than ever before that the variations shown by domesticated animals and plants are in no way distinct from variations in the wild type?

The slightest familiarity with wild species will suffice to convince any one that they differ from each other generally not by a single Mendelian difference, but by a number of small differences. The student of Mendelian heredity at least is not likely to fall into the error of identifying single Mendelian differences with the sum total of differences by which wild types and often even wild varieties differ from each other. And whenever he has had an opportunity to study these single differences in wild varieties he has found that they seem to originate and to be inherited in the same way as other Mendelian characters.

To-day it is possible, in several groups where many small differences are known, to reconstruct races of individuals containing several of these small differences that any trained systematist, ignorant of their artificial origin, would classify as good species. To deny this shows only unfamiliarity with the genetic field; to admit it is to concede all that is claimed in favor of the theory that mutants may furnish the materials for selection.

PLANNING A RESEARCH LABORATORY FOR AN INDUSTRY[1]

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DURING the last two years the importance and value of industrial research has become widely recognized; and there has been a general awakening on the part of those who control industries to the desirability of including in their organization a research laboratory to act as a nucleus of scientific knowledge for the industry, and to carry out specific investigations which are judged to be of value.

When the executive directing such an industry, however, looks for information as to how to proceed in order to establish a research laboratory, he is likely to find that the specific information which he requires is by no means easy to obtain. While there are many articles pointing out the value of a research laboratory, little has been written as to the steps which should be taken by an industry that has determined to establish one.

Let us take the hypothetical case of the vice-president of a company who, as a result of his reading, has become convinced of the desirability of establishing a research laboratory, but who, himself, has no experience in scientific work of any kind, knows only that the greater part of scientific research is done in university laboratories, and has no idea either of the cost of a laboratory, of how it should be established, or of what return he can expect from it. What is he to do in order to present a specific case to his fellow executives, or to proceed in the establishment of a laboratory, should he be empowered to do this?

The object of this paper is to suggest a specific answer to the problem of such an executive, putting the answer in such terms that it may be applicable to a large number of different industries.

In considering the organization of an industrial research laboratory we must deal first with the relation of the research laboratory to the rest of the organization of which it is a part, and secondly with the internal organization of the laboratory itself. The relation of the laboratory to the other departments of the company will be closely associated with the origin of the laboratory.

[1] Lecture delivered April 12, 1918, before the New York Section of the Society of Chemical Industry, The American Electrochemical Society, and the New York Section of the American Chemical Society.

If there is a technical scientific expert in the executive of the manufacturing company, he may have established the laboratory and become its director, and in this case the laboratory will necessarily be very closely associated with the work of the executive who initiated it.

A laboratory may also be established under a separate director, not himself associated with the executive officers of the company, but as a reference department for the executives. In this case also it will be very closely associated with the officers of the company and will tend to be more concerned with questions of policy and the introduction of new products than with any other of the problems of the company.

In a large company a research laboratory may be established as a separate department having its own organization, and be available as a reference department for all sections of the company, in which case its activities will cover a very wide field, but at the same time it will not have as direct an influence upon the policy of the company as will happen if it is closely associated with one or more of the executive officers.

Whatever the size of the industrial concern may be, the organization of the research laboratory should be responsible directly to the management.

The work of a research laboratory almost always involves questions of policy, and not merely manufacturing questions, and frequently close connection with the advertising and selling departments of the company is very necessary. In several cases where research work has been conspicuously successful, this has been the case.

Let us assume, therefore, that on the establishment of the research laboratory we are considering arrangements will be made in the organization of the company by which the laboratory will be brought into contact not only with the manufacturing sections of the company but with the financial and sales direction.

Turning next to the internal organization of an industrial research laboratory, there are two forms of organization possible. For brevity these may be spoken of as the "departmental" system and the "cell" system.

In the departmental system the organization is that familiar to most businesses. The work of the laboratory is classified into several departments: physics, chemistry, engineering, and so on, according to the number necessary to cover the field, and each of these departments has a man of suitable scientific attainments in charge of it. In a large department each of these men will in turn have assistants responsible for sections of the

department, all the heads of departments finally being responsible to the director of the laboratory. Under the alternative or cell system the laboratory consists of a number of investigators of approximately equal standing in the laboratory, each of them responsible only to the director, and each of them engaged upon some specific research. Each such investigator, of course, may be provided with assistants as may be necessary.

Each of these systems has advantages and disadvantages. Under the departmental system the advantages are strict organization, good cooperation throughout the departments, a plentiful supply of assistants for the abler men who form the heads of departments or sections of the departments. The chief disadvantage is that the system tends to stifle initiative in the younger men. While it is true that research men require to serve a considerable apprenticeship to older investigators, there comes a time when every man wishes to try to develop his own line of research on his own initiative and to carry out work by himself, and while it is quite possible to provide for such men in a departmental organization, there is some danger that men who are really capable of original work may not get the opportunity to carry it out. The cell system, on the other hand, provides a good arrangement for men of original initiative and of the self-reliant type; it enables a man to continue a single line of work by himself for a long time and to bring to a conclusion work which in a departmental organization might have been abandoned because of its apparently unremunerative character. On the other hand, the cell system tends to exaggerate the vices of such men. They tend to become secretive, to refuse cooperation, to be even resentful if their work is inquired into, while if a man who has developed a line of work for himself in a cell leaves the laboratory, it may be difficult for anybody else to take up the work, in which case a great deal of time and money is lost, and work which should have been carried forward is left unfinished. Another objection to the cell system is that men who are good organizers and who are of the type of men that can carry on work requiring many assistants do not easily find a place in it.

In practice, some system between these two systems of organization is essential and will develop in any laboratory. It is not possible to work a rigid departmental system, and, on the other hand, no cell system in its most definite form could be effective. The form of organization which is the easiest in administration is undoubtedly some modification of the departmental system, since only by this means can young students, fresh from college, acquire adequate training and at the same

time keep in touch with different branches of their subject and avoid the danger of overspecialization too early. A laboratory should therefore be organized in departments with an intra-departmental arrangement under which a young man who develops the ability to carry out his own work may be able take up work on his own initiative, still retaining his position in the department and carrying on his work under the general supervision of the chief of his department. There will always be a tendency in the departmental organization for men to desire to split away from the department to which they are attached and become semi-independent in the laboratory, and this tendency must be resisted in the organization and by the director of the laboratory. At the same time, it is important that too rigid a control should not be exercised so that men feel that they are prevented from exercising their own initiative.

A laboratory for a specific industry will generally tend to be of what has been called the "convergent" type, that is, one in which all the different sections of the laboratory representing different branches of scientific work have their energies directed towards the solution of problems relating to the same subject. The problems of such a laboratory will, therefore, all be inter-related and the work of the laboratory will be directed towards one common end.

The organization of such a convergent laboratory has been discussed in a former paper.[2] It is shown there that charts could be prepared illustrating the organization which would be available for almost any convergent laboratory, so that, if we have to work out the organization of a research laboratory which is to study any inter-related group of problems, we can do it by the construction of similar charts. Thus, we may arrange a chart showing the derivation of the branches of the subject considered from the sections of pure science involved. We can place on one side biological, physical and chemical problems, subdividing each section so that each one represents work capable of being handled by one man in the laboratory. It will now be possible to draw a new chart, showing on the circumference the different sections of the laboratory for which accommodation, apparatus and men must be provided, and showing the relation of these sections to the problem as a whole. Having worked this out, it is easy to find the amount of space and the number of men which will be required, or which the funds available will allow for each part of the work.

Now, before applying these charts for laboratory organization to a specific industry, let us look at the question of the

[2] "The Production of Scientific Knowledge," *Science*, 1917, p. 519.

physical organization of the laboratory itself: the building and scientific equipment, the cost of building, and the cost of the

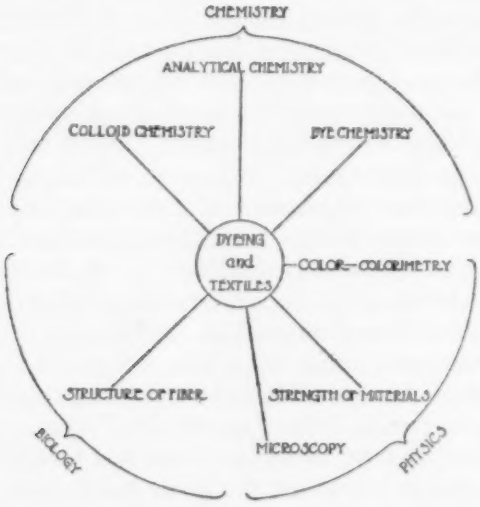

FIG. 1

maintenance and operation. It may be mentioned here that when a laboratory is under consideration by the executive of a company, the matter which usually concerns his mind are these physical details, and he is often greatly concerned with the planning and cost of the building and equipment, a matter which, as will be shown later, is quite secondary to the internal organization of the laboratory as regards effect on the work or even from a financial point of view.

The laboratory should be housed in a convenient, special building. It is very advisable that all research work under the same general direction should be conducted under the same roof, since only in this way can good cooperation between the departments be obtained, and the facilities and organization of the whole department be available to all the workers. In technical research, where it is often necessary to install model plants on a small scale, this cannot always be carried out, but, as far as possible, a research laboratory should be a real building and not merely the name for a number of scattered departments at some distance from each other.

It is a mistake for a factory to house a research laboratory in some abandoned building designed for other purposes. The annual cost of research work, as will be shown later, is very high in comparison with the cost of the building itself. The greater part of that expenditure is on the salaries of the men carrying out the work, and any inconveniences or disadvantages

which may be caused by their working conditions and surroundings can easily depress the production to an extent which renders such economics very unprofitable. The cost of the research man, in fact, is so high that it is worth while to provide him with the very best facilities for carrying out his work, since, provided money is not actually wasted on useless ornaments, these facilities will always be inexpensive in comparison with the total expenditure on the work.

Research laboratories are almost always too small, and it is really desirable that, in designing such a laboratory, some system of construction should be chosen in which expansion can be obtained by the duplication of units. This is, of course, a very difficult thing to arrange, especially in the details of the laboratory, but, nevertheless, it should certainly be aimed at by the architect, since whatever the size of the laboratory when it is designed, it is safe to prophesy that within a very few years expansion will be necessary, and if direct expansion is not possible, this will take the form of detached groups of men working in other places, an inconvenient and uneconomical arrangement.

The cost of moving in research work is not always realized. The cost of moving into a new building will be approximately half the total cost of the building, since the men will actually not be working again at full speed in less than six months, and, as a general rule, the annual expenditure is equal to the cost of the building and equipment. It is important, therefore, in designing a laboratory to arrange, if possible, that expansion may take place without any considerable rearrangement. An aid to this is to make the internal divisions of a laboratory movable as far as is possible, and while the laboratory itself should be of fireproof construction, it will be convenient to make partitions of composition board and wood wherever the fire risk does not prohibit this. In this way, rooms can easily be subdivided, combined or rearranged.

Everything that has been said as to the necessity for the provision of a satisfactory building applies also to the question of equipment, but with even greater force. It is an economic error to allow expensive men to be short of the apparatus which they require for their work. As a general rule, men will not ask for apparatus which they do not need. There are a very few men who might be considered to be apparatus collectors, and who seem to have a real anxiety to surround themselves with all forms of scientific apparatus, whether they have any use for them or not; but with the exception of these men, who are limited in number, it may be taken that when a research

worker asks for apparatus he needs it, and must have it in some form or other to continue his work.

The total cost of equipment for a physical laboratory represents about two months' cost of operation, and, if economies are to be made, it is clear they should be made in limiting the amount of work undertaken and the consequent cost of operation, rather than in depriving the employed workers of the necessary tools for their work.

From various sources of published information, as well as from personal experience, it is possible to form an estimate of the cost of a research laboratory per scientific worker employed, taking the term "scientific worker" to cover all graduate men working in the laboratory. It might seem that there would be very great variation in the cost, but, provided that we confine ourselves to laboratories of the physical and chemical type, there is a surprising agreement between the different figures, which show that cost of building and equipment for a laboratory will be between $3,000 and $4,000 per man; it may be taken therefore that the first cost of a laboratory will be about $3,500 per scientific worker employed. From the same sources the annual cost of maintenance of such a research laboratory appears to be slightly lower than the first cost. Probably $3,300 per man would be a fair estimate of the cost of maintenance, and of this we may take 60 per cent. as representing salaries and wakes and the other 40 per cent. all other expenses.

Let us attempt to apply the principles which have been laid down for the design of an industrial research laboratory, applicable to a specific industry, in such a form that they would be available for the directorate of the industry to understand to what they are committing themselves in establishing a research laboratory, and how to proceed in order to do so.

We may select as an example of a specific industry one of a technical manufacturing type dealing with engineering processes, handling chemicals, and also involving certain biological considerations; such an industry, for instance, as textile dyeing or the manufacture of leather goods. Exactly the same principles, however, would apply to industries of quite a different kind. Thus, an industry in which there are no biological considerations will not require some branches of a laboratory; it may need to substitute others in their place. For some industries, physics is of no importance and chemistry is of far more importance.

Let us, however, in order to be specific, consider the question of a plant whose business consists in the dyeing of textiles. Let us suppose that the industry is making a turn-over of $1,000,000 a year, of which 10 per cent. is net profit, and that the

directors have decided that, in order to improve their product and extend their business, possibly to diminish costs, they will at the outset undertake an expenditure of $15,000 a year on scientific research. Now, let us consider what they can do for this.

In the first place, we can decide at once how many men they can get. On the basis of $3,000 per man, they should be able to get five men for $15,000, but with very few workers in the laboratory, the cost per man will be somewhat higher, and it will be safe to assume that only four men can be obtained for the $10,000 available for salaries. The cost of the building will be about $10,000 and equipment about $5,000. Taking the basis of $2 per square foot for building as a rough approximation, we shall have a building with 5,000 square feet of floor space, or, dividing this into three floors, a building about 40 feet square. The work of the laboratory may be analyzed according to the chart shown in the figure. Dividing into the three main divisions of chemistry, physics and biology, we shall get the following sections for the work: In chemistry, we shall require an analyst and dye chemist who must understand organic chemistry, and a colloid chemist who will study the relation between the fiber and the dyes. In physics, we shall have work to do on the testing of the strength of materials and especially on colorimetry and the measurement of absorption. In biology, we shall require a man who understands the vegetable and animal fibers, their structure and their bio-chemical properties. We shall also require work on the staining of fibers and photomicrography. This will give us the chart shown.

Now, we can not hope, of course, to represent all these departments by separate men, since we can afford to have only four men, and in addition to the departments shown we must have one practical dyer having actual works experience. Our men may be grouped somewhat as follows: Our organic chemist can look after analytical chemistry as well; that is, we must get a man having experience in organic chemistry and some good knowledge of dyes, who can specialize in the study of dyestuffs and on their analysis, but who also can do what routine analytical chemistry it becomes essential for the laboratory to carry out. We may expect our colloid chemist to be a bio-chemist and to take care of the microscopy. The physicist may understand colorimetry and, at the same time, know enough general physics to be able to look after questions involving the strength of materials. We have thus accounted for three of our four skilled men, and the fourth must be the practical dyer, who should also be the director of the laboratory and should have a good training in dye chemistry and general chemistry,

with a considerable knowledge of colloid chemistry and fibers, and some knowledge of physics. Thus, the staff of our laboratory will be completed by the director, who will be a chemist who has had works experience in dyeing, and who must be given this works experience before the laboratory is commenced if a fully trained scientific research man is not already available from the works. It is of no use to take a man from the works who is not fully trained in research methods and in sympathy with scientific work, and if such a man is not already available with a knowledge of dyeing, then the best available man must be obtained from a university or elsewhere and given the works experience to learn dyeing before the construction of the laboratory is attempted.

The amount available for the salaries of these men will be about $10,000 a year, which must be distributed as seems advisable with regard to the men actually chosen. The sum should be sufficient to obtain fairly good men, as a commencing salary.

We will next consider the structure of the laboratory itself. It must be remembered that we have three floors, each of them containing about 1,600 square feet. Of these, one will be required for the library, office and the dye room, which will be a small edition of a works department containing small model machines in which all the works processes of dyeing, washing and drying can be carried out. This may occupy about half the ground floor, the other half being taken up by the library, staircase and the laboratory office, which in such a small laboratory may be united with the library. The next floor will be devoted to chemistry and may be divided into two or three rooms, while the top floor will be used for physics and will contain rooms for ordinary physical work and for colorimetry. It will also probably be used for microscopy, since it is inadvisable to have microscopes and similar instruments exposed to the fumes of a chemical laboratory.

An exactly similar design to this can be made out for any other industry, the factor of size being determined by the expenditure which it is proposed to make, and the work being dissected in accordance with the demands of the particular industry in question. Space must always be kept for a small replica of those plant operations on the investigation of which the laboratory is working, since it will often be necessary to prove the plant operations under the direct control of the men in the laboratory and under conditions which can be rigidly maintained at any required point.

Now, let us consider what returns may be expected from the work of this laboratory.

The work of an industrial research laboratory may be classified in three divisions:

A. Work undertaken on the initiative of manufacturing divisions for the inprovement of operations, for the lowering of cost, or in order to locate manufacturing difficulties.

B. Work undertaken with a view to the development of new materials or of entire, new processes. This may be initiated by the management, by manufacturing sections, by sales divisions who see the need for such materials or processes, or by the director of the laboratory or his assistants.

C. Work which deals with the fundamental theory of the subject the results of which, if successful, will lay a foundation for the expansion of the industry as a whole, along lines which usually can not be foreseen when the research work is commenced.

The work classified under Division A is, of course, common to all industrial laboratories, and many research laboratories in connection with manufacturing plants confine themselves almost entirely to problems arising from the manufacturing division.

Class B includes a large portion of the work of industrial research laboratories, and the best known successes of such laboratories are included in this division. A typical example is the development of the drawn wire tungsten filament by the research laboratory of the General Electric Company, a research which, although originating from a general research on the properties of rare metals such as would be classified under Division C, developed into a study of tungsten with the direct purpose of obtaining a satisfactory filament lamp from the metal. Another example is the manufacture of indigo by the Badische Company. Such researches usually have their basis in some more fundamental work; the industrial work on indigo, for instance, was made possible by the original chemical work on the structure of indigo carried out in the German universities, which was applied on a manufacturing scale to the preparation of the dye.

More rarely do research laboratories work on subjects classified under Division C, that is, on the fundamental theory of their subject. Yet those who do achieve the most conspicuous successes—the work of Professor Abbe on the theory of the microscope, and, indeed, all the work on applied optics at Jena —come under this heading. The great success of the Zeiss Works is directly due to the attention paid by Abbe to the development of the fundamental theories of optics. At the General Electric Laboratory at present much attention is being paid to the emission of electrons from hot bodies, and from this work

there have already developed the Coolidge x-ray tube and the Kenotron high frequency transformer, while the possibilities of application are as yet only just beginning to be realized.

In a study of the work of a special research laboratory all the work done during the year was analyzed out from a classification of the work of each part of the laboratory, and the proportionate expense which should be charged to each class of the work was found.

This analysis showed that Division A, that is, work done for the manufacturing departments, corresponded to about 15 per cent. of the work of the laboratory; Division B, work on new materials, 47 per cent.; Division C, or fundamental work, absorbed 27½ per cent., of which 22½ per cent. was devoted to the scientific work and 5 per cent. to the accompanying educational work, while work for the assistance and information of the office force is estimated at 5½ per cent.

Now, considering this division of the work of the laboratory, it will be agreed that, if proper coordination exists between the laboratory and the management of the company, work classified under A and B will certainly be reasonably remunerative, although not necessarily so completely so as to pay the dividends on the investment in the research laboratory, which is commonly expected from such an investment. The same may not appear true in the case of Division C, the fundamental work, which in the hypothetical case discussed would represent nearly a third of the total expenditure of the laboratory; nevertheless, it is probable that this section of the work would be likely to prove the most remunerative of all, and the way in which this can best be illustrated is by some examples.

Let us consider the graded examples of theoretical work in relation to their application in industry.

First, let us take the case of such work as that done by Professor Abbe on the geometrical laws which govern the formation of images by lenses. The connection between this and the manufacture of lenses is so obvious that it is at once manifest that the discovery of any new principle in the theory of lens optics will react immediately upon construction in some way, either in the form of a new product or in cheaper forms of construction.

Next, let us consider work on improved methods of testing such, for instance, as the work done by the various bureaus of standards or research on analytical methods. Here it can be seen that only the possession of an accurate method of testing will enable the manufacturer to improve his product, and to guarantee the similarity of product made at different times. Consider, for instance, the improvements in electrical meas-

uring methods and instruments which have made available the standardized electrical equipment which is now so familiar to every one.

In the third place, we may take as an example such research work as the study of the relation between inductance and capacity in alternating electrical circuits, which has had such an immense influence upon the design of alternating current electrical machinery. At the present time, of course, this is a recognized fundamental portion of electrical engineering.

Lastly, let us consider such work as that of the universities on the photo-electric effect, the diffraction of x-rays by crystals, or the emission of electrons by hot bodies. Of these, the last has already found extremely important commercial application, the second one is being adopted by several industrial research laboratories in making a study of the structure of metals, alloys and other crystalline substances, while the first, as far as I know up to the present, has not found any industrial application, and yet, it may safely be prophesied, will be of importance to industry within the next ten years.

It is almost impossible to name any class of physical or chemical scientific work, from the physics of the atom to structural organic chemistry, which will not sooner or later have a direct application and importance for the industries.

Work in a research laboratory bears a certain analogy to placer mining for gold. A man washing gold can make a living by steady, hard work, but nobody would take up placer mining with the intention of making a living by the everyday washing. Everybody hopes to find nuggets which will give them a good profit, and possibly even a fortune. In the same way a research laboratory can produce results equivalent to a large amount of its expenditure by steady work, but from a commercial point of view research is undertaken in the hope of the occasional valuable discovery rather than for the steady output of small details.

The analogy can be carried somewhat further. Just as in placer mining it is of no use looking for nuggets, and any miner who neglects the routine washing in search of nuggets is likely to starve before he finds them, in the same way a research laboratory can not look for discoveries. It can only carry on its everyday work on the problems presented to it, and hope that when some possibility of a valuable discovery presents itself it may recognize it in time to take advantage of the fact.

There is, however, one direction in which this analogy breaks down. When a man finds a nugget, he knows its value and its value is definite and certain; in research work this is not

the case. Discoveries which are thought to be valuable when made often prove worthless, while others which appear to be of no value eventually turn out to be profitable, and frequently the value of a discovery is not under the control of the laboratory because the adoption and exploitation of it may be in other hands.

It is sometimes thought that in order to put an industry into a state of complete efficiency from a scientific point of view all that is necessary is to establish a laboratory and to employ a scientific staff to carry out research work. It is quite possible, however, for such a laboratory to have no influence whatever upon the general policy of the company, and only a very slight influence upon its manufactures, the value of a laboratory depending very greatly upon the closeness of its cooperation with the other departments of the company.

It is often felt that small industries can not afford to support scientific research, but this argument is exactly as if it were suggested that small industries can not afford to support advertising. The object of spending money on research, for a small industry at any rate, is not to support the research but to be supported by it, and it is scarcely an exaggeration to say that the smaller a business is, the more important is it that it should make use of scientific research to the greatest extent possible.

A small business is at a disadvantage in comparison with a large one in regard to all its cost charges. In the purchase of raw materials, in manufacturing, and in selling, its cost per unit of output tends to be larger than in the case of big businesses, but, on the other hand, it is at a real advantage in regard to flexibility and enterprise. Any large business must necessarily be cautious and conservative. The amount at stake is so large that the penalty of error is heavy. Consider, for instance, the mere cost of allotting half a page in a catalogue of which three million copies are to be printed. It is clear that no business man will allow the introduction of a new article into a catalogue for which such an edition is necessary unless he has reason to believe that the demand will be sufficient to pay the cost involved. That is, the machinery of a large business is adapted for the sale of things for which there is a large demand, but it is difficult for it to introduce articles for which the demand will probably be limited and doubtful. Every large business is anxious to improve its goods, since it knows perfectly well that the penalty for failure to do this is extinction, but it necessarily moves with greater caution and more slowly than a small business can do. It is this very fact, rightly grasped, which enables the small business to get its start and grow in spite of the advantage in regard to cost possessed by its larger

competitor, and the growth of a small business will depend upon its supply of ideas for new products and new methods to a far greater extent than will that of the big manufacturing concern making staple products. Small businesses can therefore make far more use of a research laboratory and get a much bigger percentage return for the expenditure than any big company can hope to do. In the small business, in fact, a research laboratory closely associated with one of the high executive officers should begin to return a profit within a few months of its establishment, whereas in the case of a large company it may be years before a research laboratory can be considered to be financially successful.

The greatest difficulty in the establishment of a research laboratory in a small business is that any research laboratory will depend for its value upon the quality of the men at the head, or, if the laboratory is really small, of the man at the head, and a small business often feels that it can not afford to pay even one good scientific man. The solution of this in a technical business might be that the research man should also be an officer of the company, so that his cost is borne not only by the scientific work but also by the value of the executive position which he holds.

It may be objected that an investigator would not as a rule prove a capable business man, but there really seems to be no particular evidence for this common belief, and there are many examples of men trained in science who have proved extremely good administrators. The classic example is, of course, the organization of the great Zeiss works under Professor Abbe, but in many cases it will be found that the technical industries are directed by technical men who were themselves directly concerned with development and manufacture rather than with financial or business direction.

When the question with which this paper starts was put to a chemist much experienced in research work, and he was asked what he would say to an executive who requested information as to how to proceed to establish a research laboratory, he answered without hesitation that he would tell him to search until he found a suitable man to be director of it, and then leave it to the man to establish the laboratory. There is no doubt very much truth in this view, and the success of a laboratory must stand or fall in great measure by the quality of the man in charge of it. But it is often desirable for business men to come to some conclusion about research when they have in mind no man suitable to undertake the formation of a laboratory for them, and it is in the hope of aiding technical or business executives in such a position that the present paper has been written.

THE ROMANTIC ASPECT OF NUMBERS

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THE events of the past few years have made it clear that the mind of man is still a primitive organism in spite of its scientific veneer. This is confirmed by the fact that many of our most fundamental activities pivot around certain time-honored emblems and symbols inherited from an age when few could read or write, such, for instance, as the cross and triangle. Moreover the use of symbolism is an important factor in modern business, as the whole psychology of modern advertising is based on this ancient principle of using some particular device to stand for an idea. Evidently the value of symbolism consists in presenting an idea in such an impersonal form that each may interpret it in accordance with his own individual ideas and experience. Moreover, certain emblems call forth ideas or sentiments to which it would be impossible to give universal expression. Consider, for instance, the varying emotions called forth in a mixed audience when the Star-Spangled Banner is played or displayed. In religion especially, where ideas are frequently of such a nature as to transcend ordinary expression, symbolism has always found extensive use. Thus the symbolism used in the Scriptures is such as to make a universal appeal, independent of race or age, whereas dogmatic theology, at least as regards its formal expression, is necessarily a function of the particular time and place in which it originated.

The symbol which has always stood foremost in religion is the cross. Its most ancient form is the swastika, which has been found in the relics of the bronze age, and was common to races as widely separated as the Hindoos, Persians, Chinese, Japanese and the Indians of both North and South America. Subsequently this pagan emblem of good luck was invested with all the spiritual significance of the Christian religion, while to-day, as the Red Cross, it embodies the humanity of all the world. The triangle is another survival of primitive symbolism. In fact, the modern Red Triangle, inscribed with the trilogy "Spirit, Mind, Body," is exactly the symbol used by Pythagoras over twenty-five hundred years ago as the emblem of his pagan school of philosophy.

The symbolism developed by the pagan nations of antiquity shows clearly their materialistic tendencies and beliefs. The most extensive source of such symbolism is that found in the literature of the Greeks. Thus in the figurative language of the Greeks, Mount Ætna was the forge of Vulcan; and the moōn was the chariot of Diana; while in the last book of the Odyssey Homer tells us that while the Greeks were overwhelmed with sorrow for Achilles, the sea became violently agitated, which Nestor interpreted as the coming of Thetis and her nymphs to lament the death of her son. The most characteristic expression of this mystic symbolism is found in the Grecian oracles which were the purest fiction of the imagination, interpreting at the dictates of fancy the rustling of the leaves of the sacred oaks, or the dashing together of the bowls suspended in the sacred grove.

The ancient customs of all races show a belief in the action of numbers on the course of human events. Thus from the time of the calling of Abraham, Egypt found a mystic significance in the letters of the word Nile, the numerals represented by these letters making 365, the number of days in the year. The Persians also found the same meaning in the word Mithras. The Greeks had no number system properly speaking prior to the Trojan War, which occurred about 1200 B. C. At an early date, however, certain numerals were regarded as endowed with peculiar virtues. Thus Greece had her 7 sages; the world its 7 wonders; 7 great captains united before Thebes; every 7 years was supposed to determine a change in the nature and temperament of man; in a serious illness the 7th, 14th and 21st days were regarded as critical; while the 70th year was considered the most fatal to old men. The numeral 12 was also used as the symbol of completeness, as applied for example to the 12 signs of the zodiac; the 12 labors of Hercules, etc., and still persists in our division of day and night into 12 hours each; the division of the year into 12 months; and the commercial use of dozen.

Probably the numeral 12 was originally chosen as a standard unit because it contained so many small factors, as this is the reason why it is still retained as a base in spite of the efforts to replace it by the metric system. All primitive nations found fractions very difficult, and even the Egyptians, who were most proficient in fractions, used methods that were very long and cumbersome. It was a great advantage, therefore, to have a standard unit which could be divided into parts without giving common fractions, and 12 was such a number, as ½, ⅓, ¼ and ⅙ of 12 were all integers. The numeral 5 was

also used, this being the symbol of the Egyptian god Apis, and represented in Egyptian hieroglyphics by a five-pointed star. This latter symbol we have also inherited from the past, and it appears to-day in the stars of our national emblem. These two units, 12 and 5, appear to have been combined by the Babylonians in their so-called sexagesimal system, in which 60 is the standard unit or base. Evidently the practical reason for the choice of 60 is that it contains so many small factors that it can be subdivided to a much greater extent than 12 without involving the use of common fractions. This unit 60 is another element of our ancient heritage, appearing in our division of time and of angular measurement into 60 minutes and 60 seconds.

In developing their number symbolism the Greeks were empirical, making the material facts conform to their theories. For instance, Empedocles added a fourth element, earth, to the three elements, air, fire, and water, recognized before his time, because the moral virtues were four in number, namely force, temperance, prudence and justice. Similarly, Hippocrates regarded the numeral 5, representing the five senses, as the symbol of health; and Plato regarded the numeral 3 as representing the three faculties of the human soul, namely intelligence, will and memory, in the belief that this three-fold division appeared in the body as head, trunk and limbs, and in morals and art as the good, the true and the beautiful. Again when two warriors met in combat, the Greeks believed that the one whose name had the most letters in it would be the victor, this being regarded as the mystic reason why Achilles triumphed over Hector.

As the ideas of the Greeks became more definite and scientific they were impressed by the fact that number is the manifestation of thought in the material universe. In particular they were struck by the numerical intervals of the musical scale, from which they inferred that nature had imposed similar mathematical laws on the course of natural events. In particular they saw another expression of the same law in the intervals of the planetary system, and because of this similarity they spoke of the "music of the spheres," not as a poetic fancy but as a mathematical relation. Here again appears the numeral 7 associated with the 7 tones of music, the 7 planets known to the ancients, the 7 Pleiades, etc.

The highest development of Grecian number symbolism appeared in the system originated by Pythagoras and his school. The distinguishing feature of this system was the association of certain physical attributes with the properties of numbers.

For instance the Pythagoreans regarded 7 as the maiden's number because the sum of the digits in successive multiples of 7 produced all the other digits; for example, $7=7$; 14 gives $1+4=5$; 21 gives $2+1=3$; etc. Similarly 8 was the symbol of death since the sum of the digits in successive multiples of 8 decrease successively by 1; for example, $8=8$; 16 gives $1+6=7$; 24 gives $2+4=6$; etc. For the same reason 9 was regarded as the symbol of immortality since the sum of the digits in successive multiples of 9 remains constant; for example, $9=9$; 18 gives $1+8=9$; 27 gives $2+7=9$; etc. In short, numbers were regarded as the cause of events, and numerical operations as having their counterpart in the operation of natural laws. Numerals were regarded therefore not merely as passive symbols but as active principles of good and evil, capable of reproduction and combination by mathematical operations.

This Greek principle of number symbolism is in strong contrast to the Hebrew use of numerals in a figurative sense. The ancient Hebrews were unscientific to the last degree, and numbers had no special significance to them except as associated with certain events and occasions. For instance, the doctrine of the Trinity gave prominence to the numeral 3, and in consequence this numeral came to be naturally associated with Deity without the numeral itself being regarded as possessing any intrinsic virtues or having any causal significance. Thus the incident recorded in Genesis 18, where Abraham received three angels and worshipped one, calling him Lord, has been taken to indicate that the threefold apparition symbolized Deity to him, but there is no evidence in support of this view, because in the next chapter it appears that on the following day two angels appeared to Abraham's nephew Lot and he also worshipped one, calling him Lord. The fact is that all the ordinances and doctrines of the Old Testament were highly symbolic, using not only numerals but also including colors, objects, events and persons, regarded as antitypes in the prophetic sense, but at the same time there is no evidence anywhere in Old Testament literature that any of the intrinsic properties of numbers were even known, much less regarded as exerting any mystic influence on human destiny. The nature of the number symbolism in the Old Testament is apparent in the use of the numeral 7. The doctrine of the six days of creation followed by the rest from labor on the seventh was perpetuated in the division of time into the week of 7 days, naturally regarded as signifying the perfection of works. As the bow in the cloud, the sacred emblem of the divine covenant, revealed

7 primary colors, there was additional reason for regarding the numeral 7 in a generic sense as the symbol of completeness. The Hebrews must also have recognized a divine sanction for the figurative use of this numeral such for instance as appears in Pharaoh's dream of 7 years of plenty and 7 years of famine and its actual fulfillment; in the 7 plagues imposed on the Egyptians for their refusal to free the Israelites; in the efficacy of the 7 priests bearing 7 trumpets who encompassed Jericho 7 times to its destruction; in the fact that the child raised by Elijah sneezed 7 times; in the direction to Naaman to bathe 7 times in the Jordan; and in the 7 times 7 or 49 years which intervened between the years of Jubilee; while a further sanction to the symbolic use of this numeral was given by Christ himself in his injunction to forgiveness "not . . . until 7 times but until 70 times 7"; in casting 7 demons out of Mary Magdalene, and in the 7 words on the Cross.

This primitive aspect of sacred number symbolism, however, must not be confused with the figurative meaning given to the same numerals in New Testament literature, which shows many traces of Greek influence, especially in the mystic number symbolism used in Revelation. The importance of the type figured in Old Testament teachings, as distinguished from that of the numeral associated with the type, is apparent in such connections as the 3 days' journey of Isaac into the wilderness; and the 3 days spent by Jonah in the whale, as symbolizing the death and resurrection of Christ, the number 3 in each case being merely incidental to the type. Again the number 12 in Scripture gained its significance from the 12 patriarchs from whom sprang the 12 tribes. Its use in the New Testament may be referred in each case to this original meaning, as for example in the 12 foundations and 12 gates of the Holy City; the 144,000 of the redeemed Israelites; the 24 Elders, etc., even its use as applied to the 12 Apostles signifying the substitution of the new dispensation for the old. The numeral 40 is also conspicuous in the Old Testament, although its use is not such as to make it apparent what it signified. Thus the flood descended for 40 days; Saul, David and Solomon each reigned 40 years; the Israelites wandered 40 years in the wilderness; and Moses, Elijah and Christ each fasted 40 days.

When the New Testament was written the Hebrews had outgrown their isolation and were in close contact with Greek and Roman civilization. In fact the greater part of the New Testament was written in Greek. The effect of this Grecian influence is nowhere more apparent than in the mystic character given to number symbolism, which is especially manifest

in the Apocalypse of St. John. In this remarkable vision, numbers appear with great frequency and always with a cryptic meaning. To simply enumerate the more important instances of such usage, the number 4 is applied to the 4 beasts, the 4 angels, the 4 corners of the earth, and the 4 winds of the earth. 7 is applied to the 7 churches, the 7 spirits, the 7 stars, the 7-branched candlestick, the 7 lamps of fire, the 7 thunders, the 7 trumpets, the dragon with 7 heads and 7 crowns, the 7 seals, the 7 last plagues, and the 7 golden vials. 12 appears in the 24 elders, interpreted as the 12 patriarchs and the 12 apostles; in the 144,000 redeemed, representing 12,000 from each of the 12 tribes; in the crown of 12 stars; in the 12 foundations and 12 gates of the Holy City, and in the 12 angels at the gates; in the length of the city, 12,000 furlongs; in the height of its wall, 144 cubits; and in the 12 manner of fruits of the tree of life. The periods of time specified are equally cryptic, as used, for instance, of the 1,260 days of prophecy; the 42 months of the Gentiles' dominion; the 42 months of the dragon's power; the hour, day, month and year during which the 4 angels should slay ⅓ of mankind; the 10 days of tribulation; the time, times and half a time of the woman's concealment; and the 3½ days that the dead should lie unburied.

During the Middle Ages the attempt to reconcile the doctrines of Christianity with the classical philosophy of the Greeks resulted in the development of a school of thought called Scholasticism. Naturally the book of Revelation with its highly figurative language appealed strongly to the Schoolmen, and for centuries afforded a fertile field for speculation. One of the foremost in applying the properties of numbers to theology was the noted ecclesiastic Alcuin, who followed the example of the Greeks in investing numbers with certain physical attributes. For instance, he applied 6 to the Deity because he regarded 6, like the Greeks, as a perfect number since the sum of its divisors is $1+2+3=6$; while 8, being an imperfect number, he applied to the descendants of Noah, the number of persons in the ark being 8. Instances of this form of Scriptural interpretation are abundant. Tertullian said that these numerical details were imposed by sovereign wisdom and should not be regarded as trivial. St. Isidore of Seville wrote a special treatise on the numbers mentioned in Scripture, while St. Jerome and St. Hilaire also used this form of interpretation. St. Augustine was perhaps the greatest master of arithmology, developing the idea in his work "On Music," and in his theological works. It is interesting to note the nature of

the symbolism he employed. 3 he regarded as a divine number and 4 as a terrestrial number, their sum, 7, applying to creation. The sum of 7 and 3, or 10, he regarded as signifying knowledge of God and creation, and 40 as signifying the accomplishment of all the works of the law. An instance of how St. Augustine applied these properties of number to Scriptural exegesis is found in his interpretation of the 38 years of the paralytic mentioned in John 5:5, namely, that since 38 lacked 2 of being 40, it implied that the man lacked the accomplishment of all the works of the law by 2 items, love of God and love of man.

St. Ambroise, the spiritual guide of St. Augustine, regarded the 40 days of the flood as representing a regenerating baptism. In the 24 elders of Revelation he saw the mystic properties implied in the factors of 24, namely 1, 2, 3, 4, 6, 8, and 12. Thus 1 signified God; 2 the two testaments; 3 the Trinity; 4 the four gospels; 6 the perfect number applied to creation; 8 the beatitudes or virtues; and 12 the apostles. Pope Gregory regarded the 5 talents of the parable as representing the 5 senses of man used for his salvation; the 2 talents as the union of intelligence and work; and the 1 talent as intelligence unused. The man of 5 talents by doubling his charge made 10, a perfect number.

In England, St. Adhelme, Bishop of Sherborne, wrote a treatise in which he reduced every use of 7 occurring in the Bible to an application of the 7 gifts of the Holy Spirit. Another famous English churchman, the Venerable Bede, also made a careful study of number symbolism in the belief that God had ordained all things with number, weight and measure.

This universal belief in number symbolism held in common by the Fathers of the Catholic Church is enshrined to-day in the ritual of the Church. Thus the Church venerates 7 gifts of the Holy Spirit; recognizes 7 capital sins and 7 virtues; and has instituted 7 sacraments, 7 canonical hours, and 7 psalms of penitence.

One of the most interesting and characteristic illustrations of Medieval interpretation of Scripture in terms of number symbolism is found in a commentary on the work of Prudentius, published anonymously in the ninth century, A.D.* The reference is to Genesis 18, which relates that Abraham with 318 servants made war against 4 kings and overcame them. To understand the commentary it is necessary to bear in mind that to medieval writers 3 symbolized the Trinity, 4 was the

* "Commentaire Anonyme sur Prudence," par John M. Burnam, Paris, Picard et Fils, 1910.

terrestrial number, 6 the perfect number, 8 stood for the beatitudes or perfection of faith, and 10 for the decalog or perfection of works. To bring out the characteristic features of this example, the Latin original is given as well as the English translation.

Per trecentos fidem Sanctæ Trinitatis accipere possumus, et ita iungendum si noverimus quid possint: iste numerus id est CCC Tau littera quæ figuram crucis Christi ostendit sine dubio exprimitur: X vero et VIII perfectionem operum cum fide Sanctæ Trinitatis designant. Sexies enim terni vel ter seni X et VIII conficiunt. Hoc itaque bellum Abrahæ contra IIII reges allegorice significat bellum virtutum et vitiorum. Pater ergo fidei et prima via credendi Abram pro fratre suo Loth contra IIII reges dimicavit et vicit non in multitudine exercitus sed in trecentis X et VIII vernaculis expeditis. Sic et unusquisque nostrum pro anima sua tamquam Abraham pro fratre contra IIII reges id est contra spiritales nequitias spiritale bellum gerat cum trecentis X et VIII vernaculis id est cum auxilio Sanctæ Crucis et perfectione bonorum operum atque fide Sanctæ Trinitatis.

A free translation of this passage reads:

By 300 we are accustomed to understand faith in the Holy Trinity, and the context in this case verifies this meaning. This number CCC is the Greek τ, a letter which undoubtedly represents the cross of Christ. X and VIII, I believe, denote the perfection of works with faith in the Holy Trinity. Six taken three times, or three taken six times, make the X and VIII. And so this war of Abraham against the four kings allegorically signifies the war of the virtues and vices. Thus the father of truth and original belief, Abraham, contended for his brother Lot against four kings, and conquered not by virtue of a large trained army, but with 300, 10 and 8 light-armed servants. Just as each one of us contends for his soul, so Abraham contended for his brother against four kings, that is, waged spiritual war against spiritual iniquity with 318 servants, namely, with the aid of the Holy Cross, the perfection of good works, and faith in the Holy Trinity.

Whatever one may think of such interpretations in general, the fallacy in this particular case is obvious, for although the letter τ was actually used to represent 300 in the so-called Alexandrian notation of the Greeks, this notation was invented in the third century B.C., long after the time of Abraham, as well as long before the cross had gained its significance as a Christian emblem.

The most conspicuous use of number symbolism in the Scriptures and the one which has always exerted the strongest fascination by reason of its evident challenge to intelligence is the passage in Revelation 13:18, which reads:

Here is wisdom. Let him which hath understanding count the number of the beast; for it is the number of a man; and his number is six hundred threescore and six.

To the medieval theologians the meaning of this reference was

a never-ending source of speculation, while during the Reformation it became one of the most valued weapons in their theological arsenal.

For example, Bossuet, Bishop of Meaux, ascribed the number 666 to the Roman emperor Diocletian, persecutor of the Church. The true name of Diocletian, he said, was Diocles, taken from his mother Dioclea, and which he Latinized on his accession to the throne. Writing the name in the form Diocles Augustus and adding the Roman numerals which appear, the result is 666 as indicated below:

D = 500
I = 1
O
C = 100
L = 50
E
S

A
V = 5
G
V = 5
S
T
V = 5
S

666

Another famous instance was the interpretation given by Stifel, a notable (and notorious) mathematician of the sixteenth century. Stifel was an Augustinian monk who, following Luther's example, became a Protestant minister, and who ascribed his conversion to the fact that he noticed that the number of the beast applied to Pope Leo X. This he proved like Bossuet by writing the title in the Latin form LEO DECIMVS and adding the Roman numerals which appear. M he rejected, because, he said, it clearly stood for "mysterium." Adding the remaining numerals, the result is $L + D + C + I + V = 656$, and as this number is 10 less than the given number 666, he asserted that it distinctly implied that it referred to Leo the Tenth.

However absurd these particular attempts at interpretation may appear, the wording used by St. John is such as to make it evident that he really referred to some particular person, and probably used a symbolism familiar to a certain sect of his followers. The remarkable fact is that the meaning of this reference was forgotten almost as soon as written, and remained an unsolved riddle for eighteen centuries; while a still

more curious circumstance is that in one year, 1835, four men, Benary, Fritzsche, Hitzig and Reuss, discovered independently that it actually referred to Nero.

Apparently none of these men, nor any one since their time, has made any application of this discovery, although it seems reasonable to suppose that it might serve as a key to the entire code of Scriptural symbolism. It is worth while therefore to determine as nearly as possible the actual significance of its use.

Writing in a period of persecution when such a reference to Cæsar if made openly would mean not only the sacrifice of his own life but also the destruction of his writings, it seems natural to suppose that St. John would conceal his meaning by putting the reference in a form that would be understood only by the disciples. The Revelation was written in Greek, but the mistake made previously to 1835 was in always trying to interpret the number in terms of Greek or Latin numerals. Using the title in its Greek form but writing it in Hebrew characters, it becomes

קסרנרוז

In the number notation of the Hebrews these characters have the values

ק = 100, ס = 60, ר = 200, נ = 50, ר = 200, ו = 6, ז = 50,

the sum of which gives 666. Additional evidence in support of this interpretation is given by the fact that some ancient versions gave the number as 616 instead of 666. Writing the title in the Latin form, Emperor Nero, that is, leaving off the last letter and giving the remaining letters their Hebrew equivalents as above, the sum is 616.

The only direct evidence tending to establish the date of St. John's vision is a statement by Irenæus to the effect that it occurred at the end of the reign of Domitian, which would place the date at 95 or 96 A.D. Irenæus was a disciple of Polycarp, the Christian martyr, who was himself a disciple of St. John, and his statement therefore has a certain weight. However, Irenæus seemed to be ignorant of what was meant by the number of the beast, and from internal evidence in St. John's writings scholars have come to the conclusion that he was mistaken in regard to the date he assigned to their authorship.

The uncertainty as to the date to be assigned to Revelation is due to the fact that it is written in very rugged Greek, whereas in the Gospel of St. John the diction is far more polished. It is known that St. John died about A.D. 98 at the age of nearly 100, and if, as Irenæus said, Revelation was

written in A.D. 95 or 96, near the close of his life, there would be no possible explanation of the difference in style except by assuming that the two writings were of different authorship. To explain this discrepancy it has been suggested that Revelation was written not during the reign of Domitian as emperor but when he was City Prætor or Judge, about the year 67 A.D. Naturally a judge might well be responsible for the exile of St. John to Patmos, and Irenæus, knowing that Domitian was responsible, made the mistake of placing the act in his reign as emperor instead of during his term as prætor. As the last 30 years of St. John's life were spent at Ephesus in close association with Greeks, the earlier date assigned to Revelation would account perfectly for the more fluent style of his later writings.

To determine how far this explanation fits in with the supposition that Antichrist referred to Nero, turn to Revelation 17:10–11, where we read:

> And there are seven kings: five are fallen and one is and one is not yet come; and when he cometh he must continue a short space. And the beast that was and is not even he is the eighth, and is of the seven and goeth into perdition.

Now compare this statement with the chronology of the Cæsars during St. John's lifetime, which is as follows:

Augustus Cæsar.....	31 B.C.–14 A.D.	Birth of St. John at beginning of Christian Era.
Tiberius	14–37	
Caligula	37–41	
Claudius	41–54	
Nero	54–68	First persecution of Christians.
Galba, Otho, Vitellius	68–69	Military aspirants to the throne.
Vespasian	69–79	
Titus	79–81	
Domitian	81–96	Second persecution of Christians.
	98–100	Death of St. John.

With the exception of the three military chiefs, Galba, Otho and Vitellius, who were never actually seated on the throne, we have here a list of eight kings, fifth of whom is Nero, in whose reign occurred the first persecution of the Christians, and eighth of whom is Domitian, in whose reign occurred the second persecution. In Revelation the reference to Antichrist has always been interpretated as his personification in a man, and if, from the standpoint of the disciples, Antichrist was personified in Nero, he was no less so in Domitian, who was hardly less severe in his persecution. In fact St. John says of the beast (Rev. 13:7) that "it was given unto him to make

war with the saints and to overcome them"; and in 17:8 refers to Antichrist as "the beast that was and is not and yet is."

The meaning of all this becomes intelligible if the eight kings referred to means the eight Cæsars who ruled during St. John's lifetime. "Five are fallen and one is" puts the date of Revelation in the reign of Vespasian, A.D. 69–79, which agrees perfectly with the theory that the exile of St. John occurred in the prætorship of Domitian, about A.D. 69 or 70. "One is not yet come and when he cometh he must continue a short space" would then refer to Titus, who ruled for the short space of two years. "And the beast that was and is not, even he is the eighth, and is of the seven and goeth into perdition" becomes Domitian, the persecutor of the disciples.

With this key, nothing could be clearer than the meaning of the seventeenth chapter of Revelation. For the same reason that induced St. John to conceal the name of Nero, the name of Rome is also concealed by calling it Babylon, which ever since the Captivity had been the Hebrew synonym for civic wickedness. To make his meaning unmistakable, St. John personified Rome under the guise of a woman sitting on seven mountains, the classic seven hills of Rome, and "drunken with the blood of the saints and the blood of the martyrs of Jesus." And then referring to the great fire which occurred during the reign of Nero, or prophesying of the second great fire which occurred in the reign of Titus, he says in 18: 17–19 that "as many as trade by sea stood afar off and cried when they saw the smoke of her burning saying 'what city is like unto this great city . . . for in one hour is she made desolate.'"

If this evidence may be said to establish the date of Revelation, many of the references become clear, and give a basis for further interpretation which has so far been lacking. The popular interest in the book now manifest may therefore be an indication that this remarkable vision will no longer be wholly unintelligible, nor its study fruitless.

The various instances cited above serve to indicate the important rôle played by number symbolism in the intellectual development of mankind. Wherever mind has reacted to the stimulus of natural phenomena the number concept has resulted as the inevitable expression of the laws governing the material universe. The properties of number, first accepted as a fact, in process of time came to be regarded as symbolic, and only in modern times has the mind been able to grasp their true significance as one aspect of the great principle of functionality.

REMINISCENCES OF ALASKAN VOLCANOS[1]

By WILLIAM HEALEY DALL

SMITHSONIAN INSTITUTION

THE first author to take up the subject of Alaskan volcanos systematically was Constantine Grewingk in 1850.[2] He gathered from all previous accessible sources such data as existed on record, and his work is the classical source of such information. Later Tikhmenieff in his "History of the Russian-American Company"[3] added such supplementary reports as had been obtained by the navigators of the company's fleet on the Alaskan coast. The more important of these observations were incorporated in the chapters on Geology and History of my "Alaska and its Resources"[4] in 1870. Now that the national Geographic Society has taken up the subject of Alaskan Volcanos it seems well to put on record the scattered observations which I had been able to make during my field work for the U. S. Coast Survey, 1871 to 1880, and for the U. S. Geological Survey, 1885 to 1899.

The southernmost volcano of the Alaskan coast was named by Vancouver Mt. Calder and was regarded by him as a conspicuous peak about five thousand feet high. Later observers have found difficulty in identifying it among the other peaks of the northern part of Prince of Wales Island, and if really a volcano, it appears to be extinct and has perhaps lost in height since Vancouver's time.

The best known of Alaskan volcanos is Mount Edgecumbe on the northwest side of Sitka Sound rising from Kruzoff Island, and a most conspicuous object for navigators. It was named by Cook in 1778, after the well-known elevation on the south coast of England. It is a low flat-topped mountain with gentle slopes, the summit occupied by a crater some two thousand feet in diameter, the edge of which rises to a height of 2,855 feet according to observations by Davidson in 1867. From the summit deep gorges radiate which give rise to an equal number of torrents, and which remain filled with snow after the latter has melted from the intervening prominences of reddish volcanic material. The result is a very striking radiately striped cone of white and red, which once seen is never

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Beitr. zur Kenntniss der Nordwest-Küste Amerikas, mit den anliegenden Inseln." St. Petersburg, Karl Kray, 1850, 1 vol. 8°.

[3] St. Petersburg, E. Weimar, 1861–3; 2 vols. 8°, in Russian.

[4] Boston, Lee and Shepard, 1870, 1 vol. 8°.

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forgotten. It is said to have emitted smoke in 1796, but this is the only record of activity in historic times. It is associated with Indian legend as the home of the mythical "Thunderbird" from whence that monster issued to prey on whales. It has been many times ascended by Russian parties, as well as by Davidson in 1867, and a party from the Western Union Telegraph Expedition in 1865.

Various high mountain peaks of the St. Elias Range have been at times regarded as volcanic and the trail of mist which frequently projects from the lee side of such peaks has been taken for steam, but later observations have shown these views to be erroneous.

The high mountains, including the St. Elias and Alaska ranges, which are arched about the Gulf of Alaska, have as a keystone the only volcano in the territory which is situated at any great distance from the sea; namely Mt. Wrangell[5] which still maintains an intermittent activity.

The long line described by the Alaska peninsula and the Aleutian Islands, marking a line of weakness in the earth's crust through which plutonic forces have operated since Jurassic times, affords a splendid field of volcanic activity. Two classes of volcanos are in evidence in it: one comprising the typical volcanic cones rising to a considerable height, with evenly sloping sides and snowcapped summits; the other low and wide craters. The former are largely composed of volcanic ash and cinders, the latter of basaltic lavas. Beside these there are massive eruptions consisting of volcanic rock, syenitic, andesitic or porphyritic, of which a large part of the islands is composed. In the entrance to Sanborn harbor in the Shumagin Islands, the syenitic rock is seen penetrating from below the crevices in an arch of the Mesozoic schists, and in 1871 I found in the central ridge of the island of Unalashka a core of the same material. This observation has since been confirmed by the researches of Professor Jaggar, and pebbles of the same rock were collected in 1895 by Dr. George F. Becker, of the U. S. Geological Survey, at Iliuliuk Harbor. The greater part of the rocks of Unalashka Island are eruptive clay porphyries.

Two of the most striking peaks in the territory are found on the western side of Cook Inlet, named by the Russians Iliamna and Redoubt mountains, the latter from the fortified post on the Kenai peninsula opposite. In 1895, with Dr.

[5] Baron von Wrangell, formerly governor of Russian America, well known for his scientific publications and explorations, spelled the last syllable of his name with a double "l," which accordingly should be retained in the cases of the geographical features named for him.

St. Augustine, or Chernabura, Volcano, Cook's Inlet, Alaska, from the S.S.W. twenty miles distant. July, 1895.

Becker, we entered Tuxedni harbor near the foot of Iliamna. Here the shores rise abruptly, some thousands of feet of Mesozoic limestones wonderfully carved by the weather into turrets, castellated crags, and grand cathedral arches, which in the clear gray twilight of an Alaskan summer night presented a sublime spectacle. The depth of water is very great and we anchored with difficulty close to the shore. At the head of the harbor is a wide point, really an old Mesozoic beach uncovered by the elements, on which lay scattered ammonites, *Inoceramus* and other fossils of that ancient time. Nothing could be seen of the peak from this point, but beyond it was a small rocky bay from which we learned hunters had a trail up to the flanks of the volcano where they went for bears.

Only from the opposite side of the inlet can a good view be had of the beautiful snowwhite cone, 12,066 feet high, as measured by the Russians. It has never been ascended, and on numerous occasions has been recorded as active. On the occasion of my last visit in 1899, the spruce forest on the opposite shore of the Kenai peninsula, for many square miles, had been killed by the masses of ashes which had proceeded from an eruption which had occurred since my previous visit.

The Redoubt volcano, 11,270 feet high and a very similar cone, is situated about thirty miles to the north and east of Iliamna and has a similar history. No ascent of it is known to me.

In the southwest corner of the inlet off Kamishak Bay rises the brown cone of St. Augustine or Chernabura, the latter name meaning "black fox," a Russian nickname for the black-cowled Austin friars. This has been active within recent years. Formerly there was a boat harbor where the Aleut otter-hunters left their kayaks while they watched for their prey from the cliffs, but some years previous to our visit of 1895, when the mountain was ascended by Dr. Becker, an explosion which broke away part of the wall of the crater filled the harbor with fragments of lava and masses of ashes.

Further to the southwest the peninsula is studded with peaks some of which are volcanic; Alai and Chiginagak are the most prominent, but little is recorded of them.

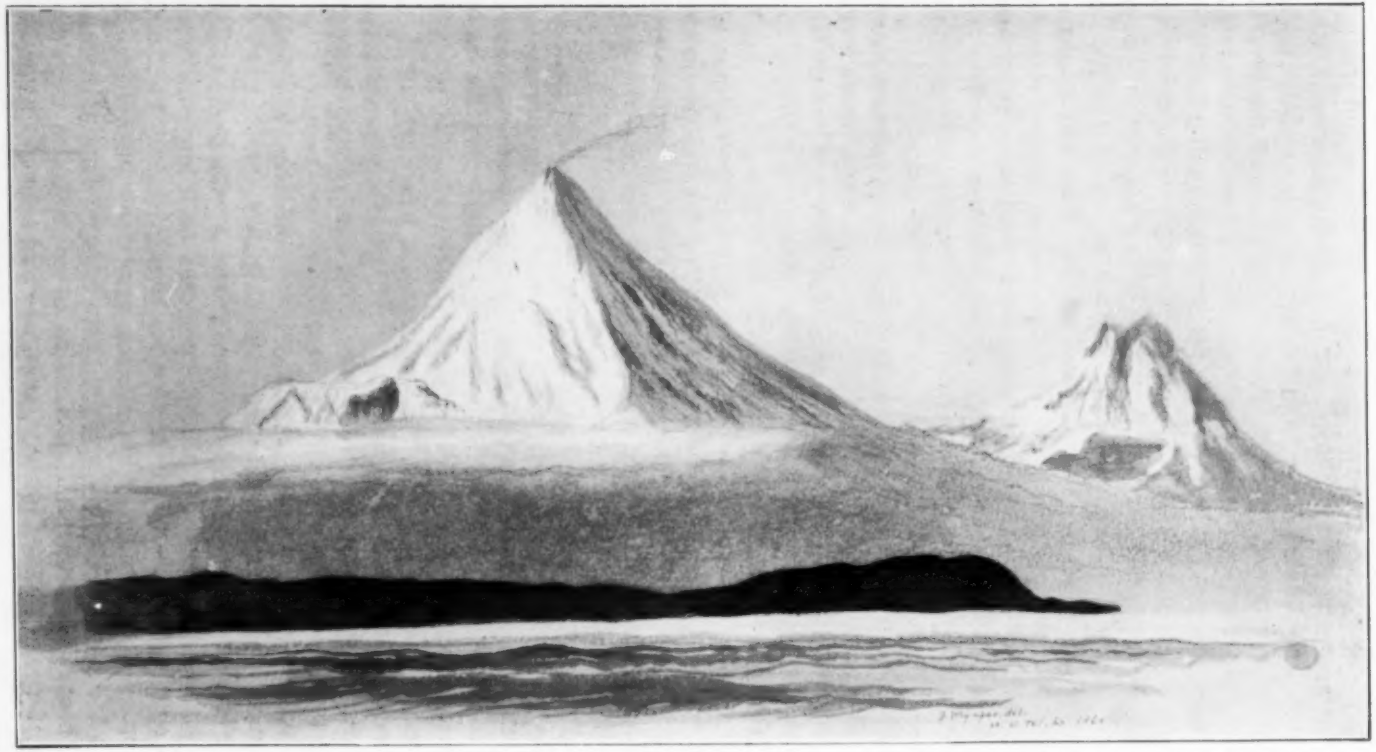
While surveying in Port Moller in 1874 for the Coast Survey, the western edge of Mt. Veniaminoff was visible from the sea with intermittent clouds of steam and blackish smoke puffing from the invisible crater at intervals. This locality I found one of the most fascinating for a geologist. The volcano in the distance, the abrupt slope toward the Pacific, the long slope toward Bering Sea, as in all the peninsular region;

Bogosloff Island, massive eruption, from the beach of the new island, Grewingk, three miles N.N.E., August, 1895.

great slabs of Mesozoic rock near the sea level sculptured by the presence of elegant fossil scallops and ammonites; the alluvium of the beaches surmounted in places with extensive shell heaps of prehistoric people, from which I picked up several interesting archeological relics, but had no time to excavate; and on a small flat point interbedded with lignite and Tertiary shales, hot springs with a temperature of 140° Fahrenheit, in which were large leathery algæ and to my amazement some water beetles skipping over the surface of water too hot to bear the hand in. Here too we shot caribou from our triangulation stations till our vessel's rigging looked like a butcher's shop with the hanging carcasses; bears were seen along the shore fishing for salmon; and on the sandbars near the entrance of the bay a herd of red-eyed yellow walrus bellowed continually.

Further westward rises the cone of Katmai volcano, from which a few years ago came the storm of ashes which devastated the island of Kadiak, and of which interesting accounts have appeared in the *National Geographic Magazine*. It is, or was, when I saw it, a cone of the typical kind, apparently about 5,000 feet in height, snowcapped and smoking. It had not been ascended at that time. The next in the line is the quiescent Pavloff volcano. Westward from it are several others apparently volcanic, and northwestward from the head of Volcano Bay, we observed, when becalmed off Vosnessenski Island in 1880, a remarkable phenomenon. On the skyline was apparently the edge of a crater from which projected upward a series of pinnacles like the teeth of a comb; as nearly as could be measured with a sextant about 200 feet high and about 40 feet in diameter at the base, shaped singly like a very tall champagne bottle, and over a dozen in number. These were probably formed by the ejection of small blobs of lava from small apertures along a crevice, cooling as they fell, until the pinnacle was built up. They are known to the natives by the name of the Aghileen pinnacles, and were mapped by me on the Coast Survey chart of 1882.

Northwest from the western end of the Alaska peninsula is the small volcanic Amak Island, composed of a low cone with the crater nearly obliterated and its fires extinct. This was occupied along the shore by myriads of walrus when I visited it in 1868, and their curiosity led them to come surging around our boat, diving under it, and rising at oar's length with distended funnel-shaped nostrils, red eyes, and tremendous tusks; a situation we found disconcerting, though they offered no violence.



PEAKS OF SHISHALDIN AND ISANOTSKI LOOMING ABOVE THE FOG ON UNIMAK ISLAND, about thirty miles distant from a point south of Unimak; from a sketch made on shipboard in 1865, by Frederick Whymper.

The island of Unimak off the end of the peninsula is perhaps the most volcanic of the larger Aleutians. The voyager to the islands *via* Unimak Pass is apt to make as his first landfall, the magnificent cone of Shishaldin rising above the banks of fog. Many times as I have seen it, I never fail to be impressed by its sublimity. If the weather be favorable, one may see by its side the lower black contorted mass of Isanotski, all that is left from a tremendous explosion of the early part of the last century. Its shattered bulk and frowning black crags form an extraordinary contrast with the tall pure white cone of Shishaldin. The latter rises nearly 9,000 feet, to the 5,525 of Isanotski. The third volcano of prominence on the island is Pagromnaia, or the Thunderer, a broad dome of about the same height as Isanotski but with very gentle smooth sloping sides, and near the shore. Shishaldin steams gently from a point slightly below the apex. It is some twenty miles inland over rough lava beds. It has never been ascended. In the *Bulletin* of the Société de Geographie for December, 1873, p. 568, an account of a supposed ascent of this mountain is given by a traveller in these regions in 1871. He was accompanied only by some natives of Unalashka who I was careful to interview on their return to Iliuliuk, and they assured me that the mountain ascended was Pagromnaia and not Shishaldin, and that the party did not approach within many miles of the latter mountain. This shows how careful one should be in identifying one's mountain.

The next large volcano to the westward is the crater of Akutan on the island of the same name. It is low, probably not over 4,000 feet at any point, and is said to have a smaller cone and crater within the larger one. It is constantly active, and frequently at Unalashka I have heard loud reports sometimes kept up for hours at regular intervals, which were said to be the work of Akutan. Once I timed them and found the intervals about eight minutes long. It sounded like distant discharges of heavy coast artillery.

On the island of Unalashka is the volcano Makushin, which is inactive. It has been ascended by Davidson in 1867 and by many others. Even the crater has been the object of a mining claim for the deposits of sulphur existing there. This mountain is reached from Makushin Bay west of Iliuliuk, by a trail between the two villages, over the center of the island. An amusing story is connected with this trail. The company leasing the seal islands, to haul seal skins from the killing grounds of St. Paul island, brought up some mules by a vessel which touched at Unalashka after a long and rough passage. The

mules were put ashore to recuperate and one wandered up the trail. Two Aleuts (who had never seen any land animal bigger than a sheep) were coming over to Iliuliuk. At the ridge of the island they met the mule, who, possibly rejoiced at the sight of a human being, lifted up his voice mightily. The cliffs re-echoed it. The Aleuts believed it was his Satanic Majesty, fell on their knees and prayed audibly. It was perhaps the first instance of a mule promoting prayer!

At the northwest head of Captains' Bay is a small, extinct, but beautifully preserved, volcano about 3,000 feet high. While making my survey of the bay, I ascended it, in 1874. The crater was complete; the portion near the walls full of black contorted columns of lava, recalling the trees in Doré's illustrations of Dante's Inferno. At the bottom was a little lake, and a small gray fox trotted among the spiky tongues of lava. This is named the Pistriakoff peak, from the puffins (Pistriaki) which nest in its walls.

I will pass over with bare mention the most interesting oceanic volcanos or rather massive eruptions, Bogosloff (St. John the Theologian) and Grewingk. Their history has been fully elucidated by Dr. C. Hart Merriam in the report of the Harriman Alaska Expedition. These masses are thrust up out of deep water. Coming down from the Arctic in the Coast Survey schooner *Yukon*, in October, 1880, we met terrible weather in Bering Sea. For sixteen days we were buffeted by living gales, with brief windless intervals which the heavy sea rendered still worse. We crept up in the fog to the entrance of Captain's Bay, but were swept by the currents to the westward and had to put to sea again, all hands worn out by the constant buffeting. In the middle of the night the watch, who had not been told of Bogosloff, was shocked to see the black mass rise out of the fog only a few cables' length away, and the men became very nervous. We decided to run for shelter as soon as it was light, trying for Chernoffski Harbor. Our only chart was dated 1795, and among the numerous rocky bays we had to find Chernoffski entrance, the only safe harbor, or come to grief. With dawn the fog cleared, the gale still blowing from the northeast. We took departure from Bogosloff under a goosewinged foresail alone, and all hands were on deck. To the westward rose the bluff end of Umnak, with a long reef stretching toward us, over which the great combers rushed in a sweep of foam, striking the foot of the cliff with a noise like thunder, and mounting two hundred feet to its very verge. It was a sight to make any seaman's blood run cold. While watching it, the fog above parted for a few moments and we saw

the snowy cone of the Vsevidoff volcano, on Umnak island, resting on the clouds, the image of perfect peace.

We made Chernoffski safely and later found that, on the old Russian map, the position of Bogosloff had been fixed from Chernoffski, so our course had been the correct one; but on the modern maps the position of the volcano was about 30 miles in error, so that we were in good fortune to have used the ancient survey to lay our course. The glimpse of Vsevidoff at such a dramatic moment was the only one had in many voyages. Usually the mountain hides its whiteness under an impenetrable mantle of fog. The Russians regarded it as less high than Makushin, but little is really known of it. I may add that only from a considerable distance at sea is the apex of Makushin differentiated from the non-volcanic peaks with which it is associated.

On the island of Umnak there are four volcanic vents beside Vsevidoff. Of these Tulikskoi on the north and the River volcano (Riecheshnoi) on the western end of the island are the most noted, but none rises to any considerable height, practically nothing is known of them and no ascents of either are on record.

Beyond Umnak lie the Islands of the Four Craters (Chetirisopochnoi). Little is known of them, except that in the hot, dry, solfataric cave of one of them was the mausoleum of which the romantic story is told in the Smithsonian Contributions to Knowledge;[6] while the mummies themselves form part of the collection of the U. S. National Museum.

To the westward again volcanic vents are numerous but hardly known, until we come to the island of Atka, where, on its northern projection, is situated the nearly extinct vent of Korovin, about 5,000 feet in height. Around it are grouped several lesser cones, Sarycheff, Sergieff, Konia, and the volcano of the Springs (Klucheffskaia). With my assistant Marcus Baker I visited the latter in August, 1873. The springs are situated high up on the flank of the peak and the Russians formerly maintained a rude sanitarium here for rheumatic and skin diseases. The water I found to have a temperature of 164° F., and it contains sulphur, lime and alum in solution. The water issues as small geysers and deposits a clay-like material of varied and brilliant colors, red, brown, yellow, light blue, and various shades of gray. The natives utilize this material to color the walls of their houses, and it was said to be reasonably permanent. The amount of water is not great and the natives stated that it had perceptibly diminished within living memory. The springs are on a bench or plateau, about

[6] No. 318, pp. 40, pl. 10, 1898, 4°.

five miles from Korovin Bay, and reached from the head of an inlet making up from the old harbor, and into which a rather large stream discharges.

West of Atka a volcano called the White Peak is said to exist on Adakh Island, but we saw nothing of it. A series of sextant angles on the north peak of Tanaga Island, said to be volcanic, gave a height of 7,108 feet, and, to the southwest, the wholly volcanic island of Garéloi (Burnt Island) about 5,500 feet, but these measurements were dependent on positions which may be incorrect, and the peaks may be higher. Grewingk from Russian sources gave them a much greater height. Off these islands, in a thick fog on our return voyage we heard for hours a series of heavy reports, like the discharges of great guns, and the Russians have reported violent activity among them during the last century.

The last active volcanos of the Aleutian chain of which we have knowledge are found on the Island of Seven Craters (Semisopochnoi) where more or less eruptive action was reported to be continuous in 1873. We caught only glimpses of the island when the prevalent fog lifted. Beyond this on the island of Little Kyska, at the entrance of the fine harbor surveyed by me in 1873, is a magnificent wall of tall slender vertical basaltic columns, like the pipes of an immense organ, which yields nothing in impressiveness to Staffa or Stromboli.

Westward of the Seven Craters the islands are composed chiefly of clay porphyry or schistose rocks, as far as observed, and there is no record of volcanic action. Northward in Bering Sea the Pribiloff Islands are wholly volcanic. On St. Paul, Miocene sandstones are included in the rock torn from the sea bottom, and contain numerous fossils.[7] When we reach Norton Sound, the islands of St. Michael and Stuart are composed of basaltic outflows, but no vent is visible in the low dome-like hills in the interior. A part of the mainland coast opposite these islands is of the same character.

Pinnacle Island, on the southeast corner of St. Mathew Island in Bering Sea, is believed to be similar in origin to Bogosloff. It has a deep gash running longitudinally through its crest, and in this fissure we thought, in 1880, we saw at night a glow as of a fire; but this may have been illusive.

In the Yukon region and northward, I know of no volcanic vents or lavas reported, but in the line of the Aleutian chain the field for the vulcanologist seems unparalleled. Even the great arc of the Japanese archipelago can offer less of interest in the form of volcanic activity.

[7] See "Fur Seals and Fur Seal Islands of the North Pacific Ocean," Part III., 1899, Gov't Printing Office, Washington, D. C., p. 539, *et seq.*

THE PROGRESS OF SCIENCE

PRESENTATION OF THE FRANKLIN MEDAL TO SIGNOR MARCONI AND DR. MENDENHALL

THE Franklin Institute made the annual presentation of its Franklin Medal, in the auditorium of the institute on May 15. This medal, founded in 1914 and awarded to "those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the institute, have done most to advance a knowledge of physical science or its applications," was awarded to Signor Guglielmo Marconi, electrical engineer and member of the Italian Senate, and to Dr. Thomas Corwin Mendenhall, physicist, of Ravenna, Ohio.

The award to Senator Marconi was made in recognition of his "brilliant inception and successful development of the application of magneto-electric waves to the transmission of signals and telegrams without the use of metallic conductors." The award to Dr. Mendenhall was made in recognition of his "fruitful and indefatigable labors in physical research, particularly his contributions to our knowledge of physical constants and electrical standards."

Count Macchi De Cellere, on behalf of the Royal Italian Government, received the Franklin Medal for Senator Marconi, and addressed the institute when the medal was presented to him. Upon the presentation of the medal to Dr. Mendenhall, he addressed the Institute on the subject of "Some Metrological Memories."

Guglielmo Marconi was born in Bologna in 1874, and carried out his first experiments in connection with his system of wireless telegraphy at Bologna in 1890. These attracted the attention of Sir William Henry Preece, electrician-in-chief of the English Postal Telegraph, who tested the apparatus with success in England; soon afterward, in cooperation with the Italian Ministry of Marine, Signor Marconi succeeded in sending messages from Spezia to a steamer 15 kilometers distant. In 1899 he established wireless communication between France and England across the English Channel. Signals were later transmitted by his system of wireless telegraphy across the Atlantic Ocean, from Poldhu, Cornwall, to St. John's, Newfoundland. In December, 1902, he was able to announce the establishment of wireless telegraphic com-

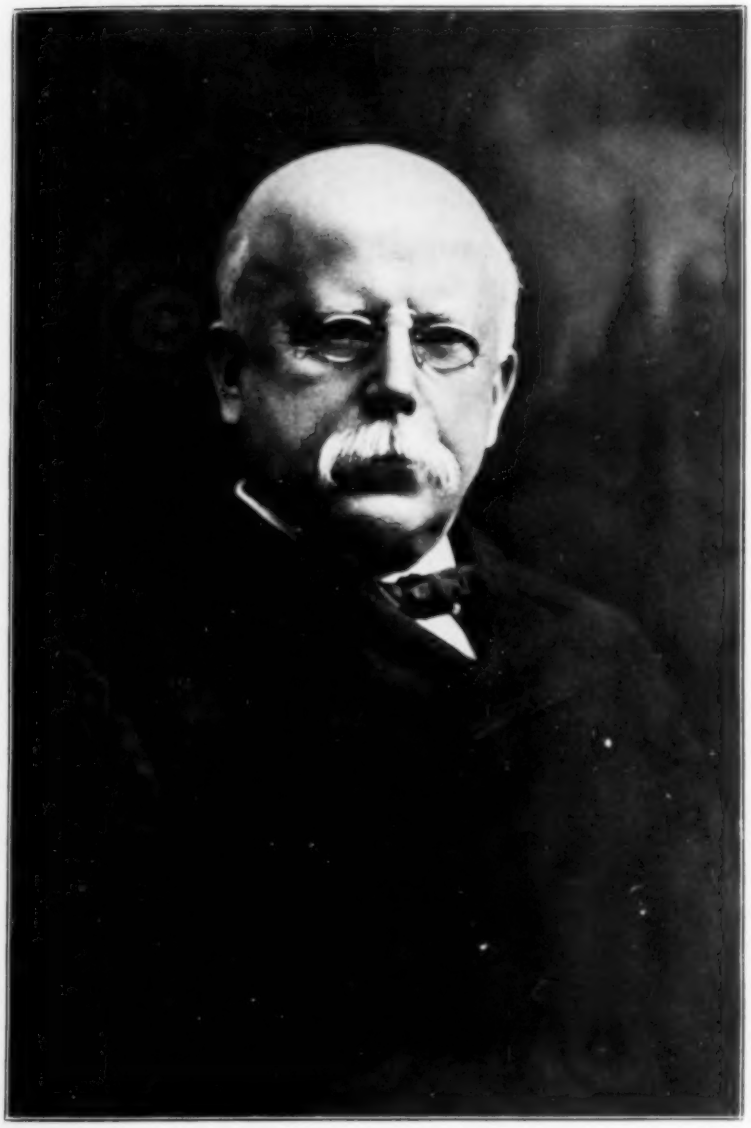
THE FRANKLIN MEDAL.

GUGLIELMO MARCONI.

On January 18, 1903, there was sent, by Signor Marconi, from the wireless station at South Wellfleet, Cape Cod, Mass., to the station at Poldhu, Cornwall, England, a distance of 3,000 miles, the message—destined soon to be historic—from the President of the United States to the King of England. This photograph was taken by A. B. Phelan exclusively for *McClure's Magazine* immediately after the sending of the message.

munication by his system between Canada and England, and in January, 1903, he transmitted a message from the President of the United States to the King of England, inaugurating wireless connection also between Cape Cod (Mass.) and Cornwall.

Thomas Corwin Mendenhall was born in Ohio in 1841. He was professor of physics at the Ohio State University from 1873 to 1878, at the Imperial University of Japan from 1878 to 1881 and again at the Ohio State University from 1881 to 1884. Dr. Mendenhall was president of the Rose Polytechnic Institute from 1886 to 1889, superintendent of U. S. Coast and Geodetic Survey from 1889 to 1894 and president of Worcester Polytechnic Institute from 1894 to 1901. At the International Electrical Congress held in Chicago in 1893, Dr. Mendenhall was chosen one of a committee of five delegates, to formulate definitions for the fun-



THOMAS CORWIN MENDENHALL.

damental units of electrical measurement: the ohm, the ampere, and the volt. The members of this committee were Ayrton, Mascart, Mendenhall, Rowland and von Helmholtz, and the definitions agreed upon are known as the "International electrical units."

THE SOLAR ECLIPSE OF JUNE 8

FROM the earliest times of which there is record a total eclipse of the sun has excited wonder and been the occasion of omens and portents. Now that its cause is understood, it is still a striking occurrence, not

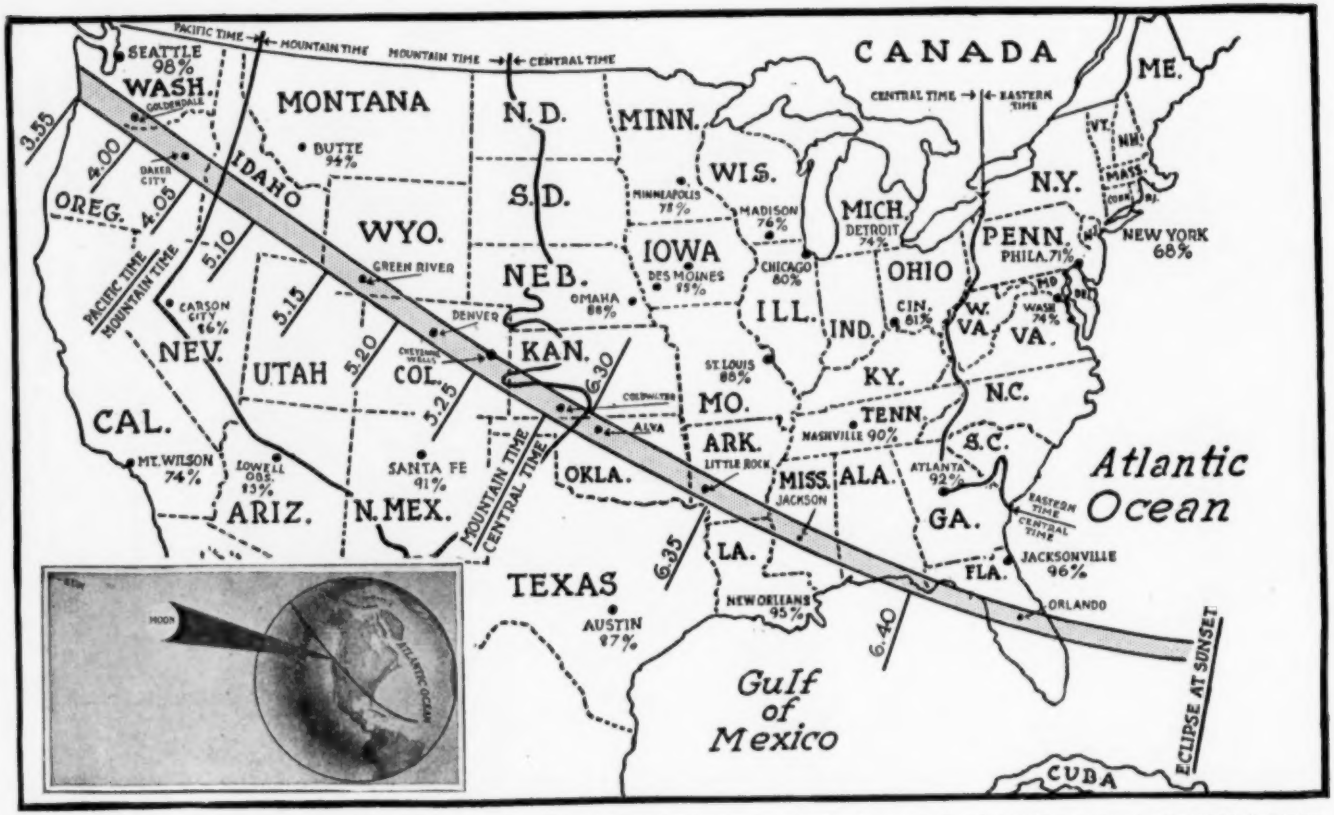


Chart from the *American Review of Reviews*, showing the path of the moon's shadow (track of totality) across the United States. The figures adjacent to the eclipse path show the standard "Summer" Time at which totality began. Outside the path of totality a partial eclipse was visible all over the United States. The percentage of the solar disk that was covered by the moon is shown at several places on the map. The diagram in the lower left corner shows how the moon, coming between the sun and the earth on June 8, blocked the sun's rays and cast a shadow on the earth.

only to people who witness its dramatic phases, but also to men of science who study its phenomena. The event is so rare, the duration is so short, the distance that must often be traveled to reach the place of observation is so great, the difficulties of arranging apparatus in an unusual place are so considerable, the chance of a cloudy sky is so disastrous, that unusual interest is excited even among astronomers.

The eclipse of June 8 was notable in that the shadow passed across the whole United States from Washington to Florida. Not for a hundred years will a total solar eclipse be visible over so large an area of the country. Though the shadow was rather narrow, the time of totality not long and the sun somewhat too near the horizon, the opportunity for observation in the Northwest was very good. The war, however, prevented the presence of any expeditions from abroad, and American observatories are much distracted from their regular work by existing conditions. It is also the case that photography has permitted the solution of many of the problems of special interest and that this can now be used in many directions apart from an eclipse. New problems, however, always arise and scientific men are now interested in the Einstein theory of relativity, according to which rays of light from the stars should be subject to deviation by gravitation when passing close to the sun, and this may be determined by photographing the sky about the sun at the time of a total eclipse.

Expeditions to the Northwest were sent from the Lick, Mount Wilson, Yerkes, Naval and other observatories and from the Smithsonian Institution and the Weather Bureau. The Chamberlin Observatory of the University of Denver is only eight miles from the middle of the shadow. The best account of the eclipse that has appeared is in a press dispatch prepared by Dr. W. W. Campbell, director of the Lick Observatory, who has now observed six total eclipses of the sun.

The Crocker Expedition from the Lick Observatory was stationed at Goldendale, Wash., situated exactly on the central line of the eclipse path. Dr. Campbell states that a few of the twenty-six photographs secured with cameras of focal lengths from eleven inches up to forty feet have been developed, and the details of coronal structure are recorded with admirable sharpness, showing that the earth's atmosphere was in a tranquil state. Four cameras of fifteen-feet focus, using plates of 14 x 17 inches, were used to record the brighter stars in the regions immediately surrounding the sun to detect, if possible, the displacements required by the Einstein hypothesis and to determine the existence of bodies such as the hypothetic planet Vulcan in the vicinity of the sun. Two spectrographs gave images of the stratum of green coronium gas enveloping the sun, and the general spectrum was recorded in good strength with two spectrographs.

The weather conditions at Goldendale were most dramatic. The prospect for a clear sky was apparently hopeless during the whole day, but a very small area of blue sky free from clouds with the sun as its center appeared exactly at the center of the total phase when all other parts of the sky were clouded. This region cleared not more than a minute before the beginning of totality and the clouds again covered the sun within less than a minute of the passing of the shadow.

THE CONSERVATION OF PLATINUM

THE country is and for many years will be urgently in need of platinum in its industrial work and

must now have it for war purposes. It is believed that aside from the large amount of platinum metals in the form of manufactured jewelry, a large part of which is in private ownership, there is less than twenty-five per cent. of the normal stock of unmanufactured platinum in this country available for the needs of the war. In an effort to fill the immediate pressing needs of the government in its war program, the War Industries Board has ordered that seventy-five per cent. of the stock of platinum in the hands of manufacturing jewelers be commandeered and also the complete stock held by refiners, importers and dealers, but this, it is said, will only fill a small gap and that temporarily.

The American Chemical Society has issued an appeal to the people not under any circumstances either during the war or afterwards to use platinum jewelry, but to conserve this metal, now priced at five times the cost of gold, for the exclusive use of the chemical and other necessary industries. The first purpose will be to obtain a sufficient supply of platinum for the needs of the war, and then to retain the production of the future for the industries. It is claimed that even before the war, as a result of the craze for platinum in jewelry, the highly important work of the chemists had been curtailed and research work, especially in the universities, handicapped by inability to meet the constantly rising price for platinum.

A movement among the women of the country to discourage platinum in jewelry has been initiated by the American Chemical Society. The Women's National League for the Conservation of Platinum has been formed as a national organization, with Mrs. Ellwood B. Spear, Cambridge, Mass., as chairman. State councils have been formed in fourteen of the leading states of the Union and even the efforts of college women have been enlisted. Already throughout the country thousands of women have signed the following pledge: "I will neither purchase nor accept as gifts jewelry and other articles made in whole or in part of platinum so that all possible supplies of this precious metal shall be available for employment where they can do the greatest good in the service of our country, and I further pledge my influence to persuade others to take the same patriotic stand."

Dr. Charles L. Parsons, secretary of the American Chemical Society, states that platinum ought not to be used in jewelry either in war time or in time of peace. It is too greatly needed for the development of chemical science and industry. The Russian mines, from which 95 per cent. of the platinum comes, are reported to be nearly exhausted, and these are now virtually in German hands. The United States has not enough for its probable war needs and, as the jewelers now use over 50 per cent. of the supply that comes into commerce, they must be held responsible for its scarcity.

SCIENTIFIC ITEMS

WE record with regret the deaths of Frederick Remsen Hutton, honorary secretary of the United Engineering Society and long dean of the faculty of engineering at Columbia University; Charles Christopher Trowbridge, assistant professor of physics in Columbia University, and of Joseph Deniker, the distinguished French anthropologist.

IN honor of Professor Emeritus John J. Stevenson, who held the chair of geology at New York University from 1871 to the time of his retirement from active service in 1909, the building to be occupied by the Faculty Club has been named Stevenson Hall. It was presented to the university at the commencement exercises on June 3.

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The Association of Modern Language Teachers of the Central West and South: C. H. Handschin.

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National Aid to Negro Education: James H. Dillard.

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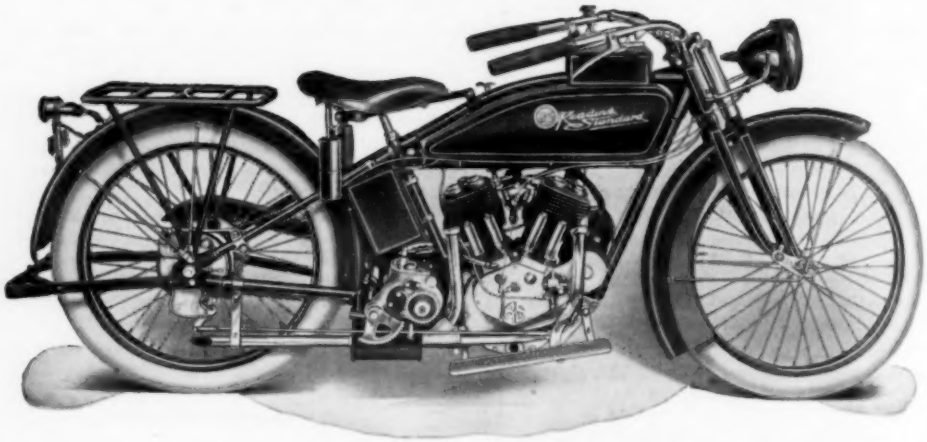

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